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CONTENTS

Chapter 1

INDIRECT COMPOSITE RESINS

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The primary objective of restorative dentistry is to rehabilitate tooth structure lost due to caries, trauma, or wear, while simultaneously restoring function, phonation, and aesthetics to the patient. Within this framework, an ideal restorative material is expected to compensate for the structural loss caused by caries or trauma, while preserving the original anatomy of the tooth, and ensuring both functional occlusion and aesthetic harmony. In contemporary dentistry, the increasing aesthetic demands of patients have prompted clinicians to adopt minimally invasive approaches and utilize restorative materials that closely mimic the color and translucency of natural teeth.(Baratieri et al., 1996; *Website*, n.d.-a)

Although composite resins are routinely used in both anterior and posterior regions due to their favorable physical and mechanical properties, high resistance to dissolution, and ability to meet aesthetic demands, their clinical performance has not yet reached an optimal level.(Tuncer et al., 2014; *Website*, n.d.-a) During polymerization, composite resins undergo volumetric shrinkage of approximately 1–4% and linear shrinkage ranging from 0.2–1.9%, a phenomenon referred to as "polymerization shrinkage." This shrinkage leads to stress accumulation at the interface between the tooth and the resin material. As a result of this stress, microgaps may form between the restoration and cavity walls, ultimately compromising marginal adaptation.(Bicalho et al., 2014)

Over time, this may result in clinical issues such as microleakage, microcracks, postoperative sensitivity, bacterial infiltration, secondary caries, and pulpal inflammation.(Bicalho et al., 2014; Tantbirojn et al., 2011) In order to overcome the disadvantages associated with polymerization shrinkage and marginal leakage, indirect composite systems have been developed. These systems are based on the principle of fabricating restorations on extraoral working models, which are then luted into pre-prepared cavities.(Hickel et al., 1998); (Mahalaxmi, 2020; Thaliyadeth et al., 2019)

The primary objectives behind the use of indirect composite resin systems include minimizing polymerization shrinkage, enhancing adhesion to tooth structure, and improving the mechanical properties of the restoration by reducing the amount of unreacted residual monomer. Recent advancements in adhesive systems have contributed significantly to the successful clinical application of indirect composite restorations.(Dietschi et al., 1995; Malmström et al., 2002)

Indirect composites are indicated for all Class I and Class II cavities, posterior teeth requiring composite restorations, patients with amalgam allergies, esthetically demanding cases, interproximal areas, subgingival margins, and in teeth with extensive substance loss—provided there is sufficient remaining tooth structure to support bonding. However, they are contraindicated in patients with poor oral hygiene, compromised periodontal health, insufficient remaining tooth structure to support adhesion, the presence of undercuts within the cavity, and in individuals with parafunctional habits such as bruxism.(Wassell et al., 2000; *Website*, n.d.-a)

The first-generation indirect composite resins were introduced in the 1980s by Touati and Mörmann for use in posterior inlays and onlays.(Touati & Pissis, 1984) These materials shared the same composition as direct composites, including an organic matrix, inorganic fillers, and coupling agents such as silane. Notably, the early first-generation indirect composites were often produced by the same manufacturers and marketed under similar names as their direct counterparts.(Nandini, 2010; Touati & Pissis, 1984)

Extensive research has been conducted to enhance the mechanical and physical properties of first-generation indirect composites. Over time, the degree of polymer conversion has been improved by approximately 6% to 44%.(Peutzfeldt,2001;Wendt, 1987)However, the chemical bond between the organic matrix and inorganic fillers in these materials was insufficient, leading to issues such as marginal gaps, microleakage, fractures, and inadequate wear resistance.

Persistent clinical shortcomings of first-generation composites, combined with limitations observed in ceramic alternatives—such as opposing tooth wear, challenges in restoring surface smoothness, and the inherent brittleness of ceramics—prompted the development of second-generation indirect composites. In contrast to their predecessors, these newer materials feature advancements in polymerization techniques, structural composition, and offer the additional benefit of fiber reinforcement to enhance mechanical performance.(Miara, 1998)

Advancements in the Polymerization Techniques of Indirect Composites

Upon initiation of light-curing in indirect composite resins, camphorquinone within the material dissociates to form free radicals, thereby triggering polymerization. This reaction results in the formation of a highly cross-linked polymer network. However, it has been reported that approximately 25–50% of the methacrylate groups remain unpolymerized.(Asmussen, 1982)

Consequently, light-curing alone is insufficient to achieve an optimal degree of polymer conversion, prompting the development of alternative polymerization methods.(Burke et al., 1991) Even with supplemental extraoral light-curing, the degree of conversion often fails to reach ideal levels. Therefore, to maximize polymerization efficiency in second-generation indirect composites, additional specific conditions—such as heat, vacuum, pressure, and an oxygen-free environment—have been employed.(Ferracane & Condon, 1992)

The supplementary polymerization techniques utilized include:

a. Heat Polymerization

For the polymerization of indirect composites, temperatures typically range between 120–140°C. A critical factor in this method is that the applied temperature must exceed the material's glass transition temperature (Tg). The glass transition temperature is a fundamental property of polymeric materials, representing the threshold at which a material shifts from a glassy to a more rubber-like, viscous state.(Eldiwany et al., 1993)

Heating increases the mobility of polymer chains, which reduces residual stress by limiting excessive cross-linking.(Viljanen et al., 2007) However, excessive heat application may lead to degradation of the composite structure. Heat can be applied using autoclaves, casting ovens, or specially designed furnaces.(Santana et al., 2009)

Post-curing with heat following initial light polymerization is effective in reducing the amount of residual monomer. This occurs through two mechanisms: first, heat facilitates additional bonding of unreacted monomers into the polymer network, enhancing conversion; second, unreacted monomers may volatilize and be removed under elevated temperature(Bagis & Rueggeberg, 2000; Santana et al., 2009)

The combination of heat and light increases the thermal energy required for achieving higher degrees of double bond conversion. This dual-curing approach was first introduced by Heraeus-Kulzer during the development of Charisma®. Compared to light polymerization alone, the combined light and heat technique has been shown to improve wear resistance by approximately 35%.(Mehl et al., 1997)

b. Polymerization in a Nitrogen Atmosphere

The presence of air, due to its oxygen content, interferes with polymerization and significantly affects the translucency and opacity of composite restorations. Oxygen entrapment within the composite can alter light reflection and scattering at the surface, compromising the aesthetic outcome.

Eliminating residual air within the material enhances translucency. This is where nitrogen pressure becomes critical—it removes entrapped oxygen before the material cures. As a result, the degree of polymer conversion and wear resistance increase, and the aesthetic properties of the material improve. Products such as BelleGlass® and Sculpture Plus® utilize this technique within a nitrogen chamber.(Nandini, 2010)

c. Soft-Start or Slow-Curing Polymerization Method

The concept of soft-curing—initiating polymerization with lower light intensity to achieve a more complete polymerization—was introduced by Mehl.(Mehl et al., 1997) Rapid polymerization may cause early rigidity of forming polymers, restricting further molecular mobility and leading to increased internal stress. The soft-start technique helps mitigate the stress caused by polymerization shrinkage. This method is implemented in systems like BelleGlass® and Cristobal®.(Nandini, 2010; L. E. S. Soares et al., 2007)

d. Electron Beam Polymerization Method

Another technique used to enhance the mechanical and physical properties of composites is electron beam irradiation.(Behr et al., 2005) Commonly applied to polymers such as polyethylene, polycarbonate, and polysulfone, this method induces either chain scission or cross-linking within the polymer structure. It reinforces the bond between the filler and resin matrix, thereby improving mechanical strength and increasing the clinical success of the restoration. However, potential drawbacks include polymer degradation and discoloration. Due to high costs, this technique is not commonly used in routine clinical practice.(Nandini, 2010)

Fiber Reinforcement

Fiber-reinforced composites were first introduced by Smith in the 1960s. These include polyethylene fibers,("Reinforcement of Complete Denture Bases with Continuous High Performance Polyethylene Fibers," 1992) carbon/graphite fibers, and glass fibers.(Meiers & Freilich, 2000)(Vallittu, 1996; Imai et al., 1999)

However, glass and polyethylene fibers are more commonly used in dentistry. The presence of fibers helps prevent crack propagation, thereby reinforcing the composite structure. The resin matrix envelops the fibers and organizes them into a controlled geometric configuration.(Butterworth et al., 2003; van Heumen et al., 2008)

Fibers arranged in a parallel orientation from one end to the other are considered unidirectional. Alternatively, fibers can also be woven or arranged in radial or mesh configurations.(Butterworth et al., 2003) The reinforcement is more effective when the long axis of the fiber is perpendicular to the direction of the applied force.(Turkaslan et al., 2009)

Numerous brands have developed various indirect composite systems for the fabrication of inlays, onlays, overlays, and crowns. These systems differ in filler content, filler ratios, and polymerization techniques.

Artglass, introduced by Heraeus Kulzer in 1995, contains 70% by weight of fillers composed of 0.7 μm barium silicate and colloidal silica. Its organic matrix is based on urethane dimethacrylate (UDMA). In addition to difunctional monomers, it includes multifunctional monomers with two to four reactive groups, facilitating higher degrees of polymer conversion.(Leinfelder, 1997) Polymerization is achieved using xenon strobe light.

UniXS, developed by Heraeus/Kulzer, operates within a light range of 320 to 500 nanometers, delivering light at 4.5 watts. A high-intensity light pulse is delivered for 20 milliseconds following an 80-millisecond dark phase. This intermittent exposure allows the polymerized resin molecules to stabilize, making the remaining unreacted carbon double bonds more reactive and accessible for conversion.(Terry & Touati, 2001) As a result, the degree of polymerization is significantly increased.

Additionally, surface application of Kevloc—an acrylonitrile copolymer—prior to light polymerization can enhance bonding to metal frameworks.

Belleglass HP

Belleglass HP was introduced in 1996 by Belle de St. Claire. It contains 0.6 μm silanized microhybrid fillers and is available in two formulations: one for dentin and one for enamel. The enamel composite contains 74% by weight and 63% by volume of borosilicate glass fillers, optimized for enhanced optical properties. The dentin composite includes 78.7% by weight and 65% by volume of barium glass fillers. The organic matrix composition also differs between the two: the enamel composite is formulated with TEGDMA, methacrylated urethane dimethacrylate, and aliphatic dimethacrylate; the dentin composite is based on BIS-GMA.

Belleglass HP is available in five different enamel shades. Its dual-curing system replicates the structural gradient of natural teeth by placing more translucent enamel over a stress-resistant, more opaque dentin base. The dentin layer is polymerized using standard light-curing methods, whereas the enamel layer undergoes heat curing. This process is performed at 140°C and 80 psi for 20 minutes in an oxygen-free, nitrogen-pressurized environment.(Terry & Touati, 2001)

Sinfony

Sinfony was developed by 3M ESPE and contains ultrafine glass or glass-ceramic fillers. It incorporates strontium aluminum borosilicate glass fillers as macrofillers at 40% by weight. As microfillers, it includes 5% by weight of pyrogenic silica, a type of amorphous silicon dioxide produced via hydrogen-oxygen flame synthesis, with primary particle sizes below 0.05 µm. The pyrogenic silica serves to occupy the spaces between the macrofillers. The resin matrix consists of multifunctional methacrylate monomers.

The system employs two polymerization units: Visio Alpha and Visio Beta. Visio Alpha uses a halogen lamp, while Visio Beta is equipped with four fluorescent tubes. Curing occurs within the wavelength range of 400–550 nm. The curing time is 15 seconds in the Alpha unit, while the Beta unit polymerizes the material at 40°C for 15 minutes.(Göhring et al., 2005; Kakaboura et al., 2003)

Another unit used for polymerization is Hyper LII, a high-intensity device containing two metal halide lamps. It delivers 150W of light for 60 seconds across a 250–600 nm wavelength spectrum.(Matsumura et al., 1997) The use of dual-light polymerization sources in this material has been shown to enhance its mechanical properties.(Satsukawa et al., 2005)

Targis

Targis was introduced by Ivoclar Vivadent in 1996. It contains a trimodal filler system composed of 77% by weight of 1 µm barium glass particles, 0.25 µm spherical silica, and 0.015–0.05 µm colloidal silica fillers. The matrix consists of conventional methacrylate-based monomers. To prevent the formation of an oxygen-inhibited layer, the restoration is coated with a glycerin-based gel (Targis Gel) and polymerized using the Targis Power light-curing unit by Ivoclar Vivadent. The polymerization cycle includes an initial 10-minute light exposure, followed by a temperature increase to 95°C over 25 minutes, and then a 5-minute cooling phase.

SR Adoro

SR Adoro is the updated version of the Targis system, also developed by Ivoclar Vivadent. It contains 63% by weight of copolymer and silicon dioxide fillers. SR Adoro is a comprehensive system composed of enamel and dentin composites as core materials. Supplementary components include an SR bonding agent for metal frameworks, a primer, dentin shades, coloring stains, incisal masses, and opaquers. The SR bonding agent features a monomer with a highly hydrophobic aliphatic hydrocarbon chain and a methacrylate-functional phosphoric ester group.

The dentin matrix differs from previous generations by using UDMA instead of BIS-GMA or TEGDMA, combined with approximately 63% by weight of copolymer-based fillers. These copolymers are manufactured by fragmenting a composite with microfillers into particles of 10–30 µm and then integrating them with additional inorganic microfillers, creating a homogeneous composite with high filler content. The primer used in this system includes 49% by weight of barium glass fillers.

Solidex

Solidex, manufactured by Shofu, contains 1 µm silicon dioxide and inorganic aluminum oxide fillers at 53% by volume, along with ceramic microfilaments.(Klymus et al., 2007) The resin matrix is composed of 25% by weight of multifunctional resin polymers and 22% conventional monomers with photoinitiators. The system includes various materials such as metal primers, cervical, incisal, body, opaque composites, and translucent shades.

Polymerization is performed using the Solidilite system, which employs four halogen lamps operating at 55°C and a wavelength range of 420–480 nm. The Sublit polymerization unit is designed for preliminary or short-term curing without removing the restoration from the model during the shaping process.

Sculpture Plus

Sculpture Plus is an indirect nano-hybrid composite system introduced by Pentron. Its filler components include silanized particles such as barium borosilicate glass, nano-sized silica, zirconium silicate, as well as initiators, accelerators, stabilizers, and pigments.

The resin matrix contains difunctional methacrylate monomers including PCBis-GMA, EBPADMA, BIS-GMA, UDMA, and HDDMA. A small amount of aluminum oxide (Al_2O_3) is also incorporated. The system is available in body, incisal, semi-opaque, and opaque shades.

Sculpture Plus features a proprietary polymerization process in which light is applied automatically both before and during polymerization under pressure. The system includes two curing cycles: an initial structuring cycle followed by a final curing cycle upon completion of the restoration. The material is compressed in a nitrogen atmosphere and subjected to a total of 8 minutes of processing: a 3-minute exposure to high-intensity light followed by 5 minutes of pressure application.

Tescera ATL

Tescera ATL, developed by Bisco Inc., distinguishes itself from other systems by its significantly higher content of inorganic ceramic microfillers. This material offers the combined advantages of both composites and ceramics while minimizing their respective limitations. The fillers are silanized to ensure strong chemical bonding with the organic resin matrix. Increased microfiller concentration has been shown to enhance clinical performance. Reinforcing particles with a diameter of approximately 1 μm are incorporated to act as crack stoppers.

The dentin composite is a hybrid containing 85% by weight and 73% by volume of filler content. Body and incisal composites are composed of reinforced microfillers at 70% by weight. The average particle size of this composite system is approximately 50 nanometers.

Polymerization is conducted using both light and heat, within a water-submerged curing chamber. During the placement of the dentin layer, 60 psi of pressure is applied within the light chamber to eliminate voids and bubbles. This chamber also contains white ceramic beads to reflect and diffuse light evenly across the composite surface. Each individual layer is light-cured for 2 minutes. Secondary polymerization takes place in a heated water bath, which includes a system designed to remove residual oxygen from the curing environment.

Final curing of the restoration is performed using a combined light and heat cycle that peaks at 130°C and then gradually cools to approximately 90°C before pressure is released. The full pressure cycle operates at 60 psi.(Douglas RD,2000)

Paradigm MZ100

Paradigm MZ100, developed by 3M ESPE, is an alternative to porcelain blocks for CEREC restorations. It contains ultra-fine zirconia-silica filler particles produced via a sol-gel process, forming nanostructured zirconia dispersed within an amorphous silica matrix.

The material incorporates 85% by weight of ultrafine zirconia-silica ceramic fillers. These particles are spherical in shape, with an average size of approximately 0.6 μm. The high filler load is supported by a highly cross-linked polymer matrix composed of BIS-GMA, TEGDMA, and a ternary initiator system, which enhances the material's structural integrity.

Vita Zeta LC

Vita Zeta LC, produced by Vita Zahnfabrik, utilizes nanofiller particles that contribute to high translucency and a natural light-scattering effect. It contains 44.3% by weight of multiphase feldspathic glass and silicon dioxide fillers. The material is cured using the Dentacolor system, which operates at an average temperature of 40°C and a light wavelength range of 350–500 nm to achieve additional light polymerization.

2nd-GENERATION INDIRECT COMPOSITES:

Mechanical Properties

The incorporation of additional polymerization techniques and increased inorganic filler content in second-generation indirect composites has led to improvements in flexural strength and elastic modulus. Although a higher degree of polymer conversion has been achieved, this does not always translate into superior mechanical properties. This is due to the influence of multiple factors such as resin matrix composition, filler particle size, distribution, and content.

Numerous studies have demonstrated that increasing the filler loading enhances the mechanical performance of composite resins.(Da Fonte Porto Carreiro et al., 2004; *Website*, n.d.-b) For example, Chung et al. reported a positive correlation between filler content and both tensile strength and hardness of resin composites.(Chung, 1990)

In addition to the amount of filler, the nature of the filler also plays a significant role in determining mechanical properties. Neves et al. observed that higher filler content directly affects material hardness.(Neves et al., 2002) In their study, indirect composites with lower filler concentrations—such as Sinfony® and Vita Zeta®, with filler loadings of approximately 50% and 45–48% respectively—exhibited inferior mechanical performance.(Borba et al., 2009)

The polymerization method also has a substantial impact on composite hardness. Despite having a lower filler content, Targis® showed the highest microhardness among tested indirect composites, which Miranda et al. attributed to the specific polymerization method employed.(Nandini, 2010)

Filler particle size, shape, and the strength of the bond between fillers and the matrix are key factors affecting wear resistance. Studies have shown that chemical treatments used to bond fillers to the matrix can reduce wear over time.[6] In a study by Bayne et al., Concept® exhibited lower wear compared to BelleGlass®, which was attributed to the use of microfill fillers, smaller particle sizes, and reduced interparticle spacing. BelleGlass® also demonstrated lower wear resistance compared to Artglass® and

Targis®, likely due to differences in filler volume.("Protection Hypothesis for Composite Wear," 1992)

Visible wear in indirect materials may also be linked to the integration of multifunctional monomers, which help regulate cross-linked carbon chains—potentially contributing to both improved physical and mechanical properties, as well as enhanced wear resistance.(Leinfelder, 1997; "Protection Hypothesis for Composite Wear," 1992))

Optical Properties

Over time, indirect composite resins may undergo surface degradation and hardening, which, along with chemical reactions involving tertiary amines and the migration of filler particles toward the surface, can result in altered optical characteristics—particularly in terms of color stability.(O'Brien, 2002)

This unpredictable color shift may be associated with the type of polymerization used and the number of remaining double bonds in the polymer network.In a study conducted by Papadopoulos et al., accelerated aging and post-polymerization processes led to perceptible lightening and green-yellow or green-blue discolorations in indirect composites. However, these changes were still considered clinically acceptable.(Papadopoulos et al., 2010)

Douglas also investigated the color stability of indirect composites following accelerated aging. His study demonstrated that Artglass, Zeta, Targis, and BelleGlass HP all exhibited color changes within clinically acceptable limits. Among these, Zeta showed the least discoloration, followed by Artglass. Although Targis also remained within acceptable parameters, it exhibited the most significant discoloration among the materials tested.(Douglas, 2000)

Marginal Adaptation and Microleakage

One of the primary motivations for developing indirect composite resins was to address the polymerization shrinkage and associated microleakage commonly observed in direct composite restorations. A substantial body of research has been conducted to evaluate the clinical performance of indirect composites in terms of marginal adaptation and microleakage.

For instance, Scheibenbogen et al. conducted a two-year clinical study comparing marginal integrity between direct and indirect composite restorations. The study found that 60% of indirect restorations achieved an alpha score, compared to 40% in direct restorations.(Scheibenbogen-Fuchsbrunner et al., 1999) Similarly, Van Dijken et al. performed an

11-year clinical evaluation comparing direct composite restorations with indirect inlay and onlay restorations. In terms of marginal discoloration, 64% of direct composites received an alpha score, whereas 93.2% of indirect restorations achieved the same.(van Dijken, 2000)

An in vitro study by Puy et al. used SEM imaging to evaluate the marginal adaptation of indirect composite inlays and reported excellent marginal fit, consistent with findings from other studies.(Llena Puy et al., 1993)

Numerous additional studies have corroborated these findings, demonstrating that indirect composite restorations exhibit significantly reduced microleakage and superior marginal adaptation compared to their direct counterparts.(Fruits et al., 2006; Robinson et al., 1987)

Surface Properties

Surface roughness in indirect composite resins is directly associated with increased plaque accumulation, which may ultimately lead to the development of secondary caries. Therefore, achieving smoother surfaces and employing an effective polishing protocol are critical for prolonging the clinical longevity of indirect restorations. Biofilm formation and plaque accumulation are influenced by the quality of the finishing surface, which depends on filler particle size and the type of resin matrix. Heavier yet smaller filler particles tend to yield smoother surfaces, resulting in reduced biofilm adhesion. Surface roughness typically ranges from 6 to 8 µm. Polishing with diamond paste has been shown to produce smoother surfaces. Additionally, the presence of residual monomers contributes to bacterial adhesion, highlighting the importance of meticulous polishing.(Ikeda et al., 2007)

The surface characteristics of indirect composites also play a vital role in bonding to the tooth substrate. Surface conditioning techniques have a direct impact on adhesion. For example, the use of hydrofluoric acid for surface etching may lead to microstructural damage by dissolving inorganic particles.(Ikeda et al., 2007; Lucena-Martín et al., 2001)

The most effective method for increasing surface energy is airborne-particle abrasion with aluminum oxide particles for approximately 10 seconds.(C. J. Soares et al., 2005) This process results in non-selective degradation of the resin matrix, thereby enhancing adhesive performance. According to Soares, the application of silane following sandblasting further improves bond strength.(C. J. Soares et al., 2004) Given the similarities in the composition of most indirect composite materials, a standardized surface treatment protocol can generally be applied across different systems without adverse effects.

Resin-composite Blocks for Dental CAD/CAM Applications

Currently, two primary categories of materials are utilized for esthetic indirect restorations fabricated using CAD/CAM systems: glass-ceramics/ceramics and resin-based composites. Resin composites are characterized by a polymer matrix reinforced with various types of fillers, which may be inorganic (such as ceramics, glasses, or glass-ceramics), organic, or a combination of both(Ferracane, 2011).

Although glass-ceramics and ceramics typically outperform resin composites in terms of mechanical strength and wear resistance, resin composites offer practical advantages that justify their use in certain clinical scenarios. Notably, they are easier to process and allow for convenient intraoral repair of minor defects resulting from functional wear. These repairs can often be accomplished through surface roughening—by sandblasting or bur abrasion—followed by the application of a compatible resin composite material.

Moreover, resin-composite blocks tend to exhibit reduced susceptibility to chipping during the milling phase of CAD/CAM fabrication, which enhances their handling and efficiency in laboratory procedures(Tsitrou et al., 2007).

The first commercially introduced resin composite material for CAD/CAM systems was **Paradigm MZ100** (3M ESPE, St. Paul, MN, USA), developed through industrial polymerization of the well-known direct restorative composite **Z100**. This factory-controlled polymerization process enhanced the mechanical properties of Paradigm MZ100 compared to Z100, yielding improved values such as a flexural strength of approximately 130 MPa and a fracture toughness (KIC) of around 0.8 MPa·m½ (“Resin Composite Blocks via High-Pressure High-Temperature Polymerization,” 2012).

Additionally, several in vitro studies have demonstrated favorable fatigue resistance of this material.(Magne & Knezevic, 2009; Tsitrou et al., 2010; Kassem et al., 2012)

Lava Ultimate (3M ESPE) was later introduced as a successor to Paradigm MZ100. It was likely manufactured under modified thermal and pressure conditions, which contributed to slightly enhanced mechanical characteristics, including a flexural strength of ~155 MPa and KIC of ~0.9 MPa·m½ (Thornton and Ruse, 2014).

While 3M ESPE composites are produced through conventional methods—incorporating filler particles into a monomer matrix—**VITA Zahn-**

fabrik (Bad Säckingen, Germany) launched a different approach in early 2013 with the introduction of **Enamic**. This innovative material is created by infiltrating a pre-sintered ceramic scaffold with a monomer mixture. The result is a resin-ceramic hybrid with a filler content of approximately 70% by volume. This higher filler load has been linked to improved mechanical performance in comparison to Lava Ultimate (Coldea et al., 2013; Thornton and Ruse, 2014).

In an effort to significantly enhance the performance characteristics of resin composites used in CAD/CAM systems, a research team led by Michaël Sadoun investigated the polymerization of both commercial and experimental direct restorative resin composites under **high-pressure (HP, 300 MPa)** and **high-temperature (HT, 180–200°C)** conditions (Nguyen et al., 2013). The resulting HP/HT-polymerized resin composite blocks demonstrated remarkably improved mechanical performance compared to their light-cured counterparts, and in many aspects, even outperformed established commercial materials like Paradigm. These enhancements included substantially increased flexural strength, Weibull modulus, surface hardness, and overall density. Notably, the flexural strength of these materials exceeded 200 MPa—higher than previously recorded values for dental resin composites and, in some cases, surpassing that of certain glass-ceramic materials.

Unfilled urethane-based polymers subjected to the same HP/HT process achieved flexural strength values of around 190 MPa and fracture toughness (KIC) of approximately 1.35 MPa·m½, clearly outperforming many currently available resin-composite blocks. Further structural investigation of these HP/HT-processed matrices using dynamic mechanical analysis (DMA) revealed an increase in cross-link density. However, it was also found that either excessively high temperatures or the absence of initiators during the process negatively affected the viscoelastic properties of the materials (Béhin et al., 2014).

Surface analysis performed through atomic force microscopy (AFM) confirmed that HP/HT polymerization caused noticeable alterations in surface morphology. Depending on other processing conditions, this resulted in larger and denser nodules or, conversely, in smaller, less defined nodular formations with lower frequency and size.

Two potential advantages have been proposed for HP/HT polymerization: eliminating the need for initiators and reducing monomer release. Experimental data confirmed the second hypothesis while refuting the first. The inclusion of an initiator was shown to contribute positively to polymer network development, yet monomer release was drastically minimized, often dropping below the detection limits of high-performance liquid chromatography (HPLC) equipment (Phan et al., 2014). While the performance differences between initiated and non-initiated polymers were minimal, the potential for reducing discoloration associated with aging—often attributed to initiators—remains a relevant consideration for future research.

In summary, HP/HT polymerization has opened a promising and innovative pathway in the development of high-performance dental resin composites. If adapted successfully for industrial-scale production, this process could lead to the commercialization of next-generation CAD/CAM resin-composite blocks. Still, it is important to recognize that these materials remain resin-based in nature and, therefore, are unlikely to surpass the overall physical and optical performance of ceramic or glass-ceramic blocks. As such, clinical decision-making should always be guided by the specific needs of the patient, weighing the relative strengths and limitations of each material class. Only long-term clinical trials can provide definitive evidence regarding the in vivo success of these innovations. What is certain, however, is that CAD/CAM technology has established a permanent role in modern dentistry, marking a transformative shift in both materials and workflows—one that is still in its early stages.

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Chapter 2

THE USE OF PRF IN DENTAL PRACTICE

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Autologous platelet concentrate applications have emerged as a promising therapeutic approach in the fields of dentistry and medicine, and they have been utilized in dental practice for a long time (Bettega and Schir, 2012; Treuting and Morton, 2012; Anitua et al., 2015a). Numerous studies have been conducted and evaluated to regenerate hard and soft tissues lost due to disease (Urban and Monje, 2019). The diverse origins and proliferative capacities of the structures composing these tissues make their regeneration more challenging (Meshram et al., 2015). A wide variety of dental materials and products—including membranes, graft materials, and enamel matrix derivatives—have been used for tissue regeneration (Zhang et al., 2022). Considering the potential disadvantages of these materials, such as foreign body reactions, the risk of pathogen transmission, membrane perforation, and high cost, the use of autologous products (platelet concentrates) becomes increasingly advantageous (Vroom et al., 2022; Badiee et al., 2022).

Soft and hard tissue regeneration is of great importance in dental treatments. Regeneration encompasses a complex healing and tissue repair process involving multiple biological events. Various grafts, biomaterials, growth factors, stem cells, and natural or synthetic materials are used to support this process (Brown, Handorf, Jeon, and Li, 2013). Currently, various surgical procedures and dental materials are employed for the reconstruction of defects in the maxilla and mandible, as well as for augmentation of the residual alveolar ridge (Rodella and Bonazza, 2015). Platelet-rich products derived from the patient's own blood promote healing in both hard and soft tissues by enabling the controlled release of various proteins and growth factors (Table 1). These products, which contain the essential components for natural wound healing, do not require biochemical processing and are easy to apply (Koçyiğit et al., 2012).

TGF - β	Transforming growth factor beta
PDGF	Platelet-derived growth factor
VEGF	Vascular endothelial growth factor
EGF	Epidermal growth factor
IGF	Insulin-like growth factor
IL - β	Interleukin beta
ECGF	Endothelial cell growth factor
VPE	Vacuolar processing enzyme

Table 1. *Factors present in platelet granules that affect cell proliferation, angiogenesis, and matrix remodeling in the applied area.*

When activated, platelets become embedded within the fibrin matrix and begin to release growth factors. These growth factors stimulate regeneration and tissue healing, while also contributing to structural formation together with fibrin. Several studies have investigated the effectiveness of platelets in wound healing, and successful treatment outcomes have been reported in oral surgeries (Rodella and Bonazza, 2015). In another study, it was demonstrated that platelet-rich fibrin (PRF) application induced the proliferation of osteoblasts, preadipocytes, gingival fibroblasts, and dermal prekeratinocyte cells (Ehrenfest, Rasmusson, and Odin, 2009).

Historical Development of Platelet-Rich Products

The term "platelet-rich plasma (PRP)" was first introduced by Kingsley in 1954 to emphasize the role of platelet concentrates in coagulation (Kingsley, 1954). A combination of fibrinogen, platelets, and thrombin was subsequently employed in general surgery, ophthalmology, and neurosurgery (Pearl et al., 1977). The positive effects of platelet-rich products on wound healing were demonstrated by Knighton et al. in 1986 (Knighton et al., 1986). In 1997, platelet concentrates were applied in maxillofacial surgeries (Whitman, Berry, and Green, 1997). In 1998, the term PRP was used in a study by Marx et al., in which PRP was produced using a device similar to a cell separator (Marx et al., 1998). Short-term applications of PRP revealed some limitations, such as lengthy preparation times and the use of animal-derived products, leading to the development of a second-generation platelet concentrate (Choukroun et al., 2004).

Platelet-Rich Plasma (PRP)

PRP is a rich source of platelets and growth factors released from platelet alpha granules. It can be prepared using single or double centrifugation steps, which enable the separation of red blood cells. Calcium chloride ($CaCl_2$) or thrombin is used as an anticoagulant during the PRP preparation process to inactivate platelets in the production tubes (Xu et al., 2020). Various studies have reported on preparation times, centrifugal force, blood volume, and rotational speed during PRP processing (Xu et al., 2020). Piao et al. (2017) stated that the quality of PRP is not only affected by these technical parameters, but also by the intrinsic quality and functionality of the platelets themselves (Piao, Park, and Jo, 2017). The platelet concentration in PRP can be up to nine times greater than that in whole blood (Etulain, 2018). After preparation, PRP releases approximately 95% of its contained growth factors within one hour, and its biological activity lasts for up to 7 days. Therefore, it is recommended that PRP be applied to the target area within 4 hours (some studies report up to 8 hours) of preparation, considering the release kinetics of the growth factors (Xu et al., 2020). Multiple procedural steps and the inclusion of animal-derived components are among the disadvantages of PRP (Piao, Park, and Jo, 2017; Miron et al., 2017).

Platelet-Rich Fibrin (PRF)

Due to the limitations associated with PRP, such as the need for non-autologous additives (e.g., calcium chloride, thrombin), complex preparation protocols, and difficulties in intraoperative application (due to its liquid form), researchers turned to the development of a second-generation platelet concentrate (Dohan Ehrenfest et al., 2010). PRF was first introduced in France in 2001 by Choukroun et al., using a centrifugation cycle at 2700 rpm for 12 minutes to collect a platelet concentrate lacking clotting factors in the upper layer of the tube (Choukroun et al., 2004; Choukroun et al., 2006).

PRF is a second-generation platelet product that allows for the formation of a platelet-rich membrane containing growth factors. Its preparation requires no anticoagulants. The formation of a fibrin clot facilitates sustained release of growth factors and provides a scaffold for migrating cells (Jayadevan et al., 2021). Leukocyte-rich PRF (L-PRF) incorporates white blood cells (WBCs) into the fibrin matrix, contributing to wound healing by secreting growth factors and enhancing immune support (Adamson, 2009; Ghasemzadeh and Hosseini, 2015). During PRF preparation, venous blood is drawn from the patient and transferred into 10 mL glass-coated plastic tubes without anticoagulants. It is centrifuged at 3000 rpm for 10 minutes (Dohan et al., 2006a). The absence of anticoagulants necessitates rapid transfer of the blood into the centrifuge to prevent disorganized fibrin formation, which would reduce the likelihood of obtaining PRF. Fibrin polymerization is activated when venous blood contacts the silica surface of the tube. Fibrinogen is converted into fibrin by autologous thrombin, and leukocytes and platelets are trapped within the fibrin matrix (Dohan et al., 2006a, 2006b, 2006c). After centrifugation, the contents of the tube are layered as follows from top to bottom: acellular plasma, PRF, and red blood cells (Figure 1).

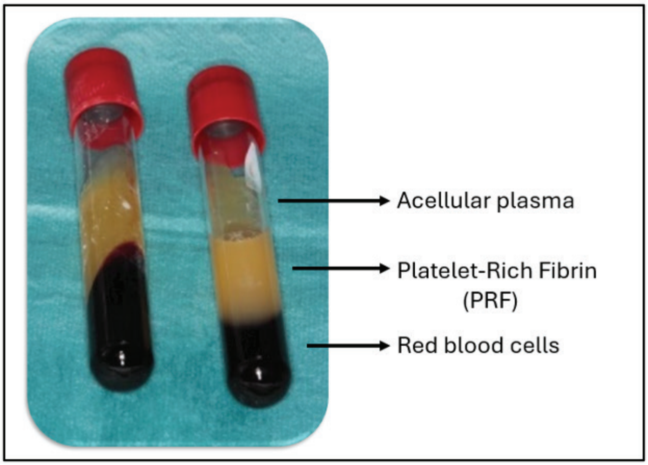

Figure 1. *Layers formed after centrifugation.*

It has been stated that three factors are essential to enhance the regenerative potential of bioactive structures: a three-dimensional matrix, a cellular component, and bioactive growth factors. The second-generation platelet product, PRF, fulfills all of these characteristics. (Choukroun et al., 2017) (Table 2)

	Requirements for Tissue Repair		***Properties of PRF***
1	**Three-Dimensional Matrix**	It supports tissue growth.	Fibrin: serves as a scaffold surface material.
2	**Cellular Structure**	It affects tissue growth.	Leukocytes, macrophages, neutrophils, platelets: facilitate the accumulation of regenerative cells at the defect site.
3	**Bioactive Growth Factors**	It facilitates cell differentiation.	Fibrin: serves as a reservoir for the release of growth factors over a period of 10 to 14 days.

Table 2. *Comparison of the factors required for tissue repair and the properties of PRF.*

Content and Preparation of PRF

Platelet-rich fibrin (PRF), when produced using standardized protocols, comprises all the biological components inherently present in peripheral blood, including platelets, leukocytes, cytokines, stem cells, monocytes, T and B lymphocytes, neutrophilic granulocytes, and fibrin (Ghanaati et al., 2014). One of the major advantages of PRF is its ease of preparation and application by clinicians without the requirement for specialized equipment or additional medical instruments. The process involves the collection of venous blood from the patient into 10 mL glass-coated plastic tubes devoid of anticoagulants. Subsequently, the blood is centrifuged either at 3000 rpm for 10 minutes or at 2700 rpm for 12 minutes. Due to the absence of anticoagulants, coagulation begins immediately upon transfer of the blood into the tube (Raja and Naidu, 2008). Post-centrifugation, three distinct layers become evident. The middle layer, representing the PRF clot, is enriched with platelets and leukocytes and exhibits a three-dimensional fibrin matrix that supports cellular entrapment and release (Dohan et al., 2006b; Dohan et al., 2006c).

Titanium-Prepared Platelet-Rich Fibrin (T-PRF)

Due to the presence of leukocytes, PRF prepared using standard procedures is also referred to as L-PRF. (Tunalı et al., 2014) Numerous studies have been conducted to improve the fibrin structure and cellular content. (Dohan Ehrenfest et al., 2010) Tunalı and colleagues proposed the idea of preparing PRF in titanium tubes, which are made from a biocompatible material. (Tunalı et al., 2014) Venous blood was transferred into titanium tubes and centrifuged at 2800 rpm for 12 minutes. The resulting fibrin structure was reported to be denser and to contain thicker filaments compared to L-PRF, although the platelet and leukocyte content was similar. (Tunalı et al., 2014; Olgun et al., 2018) In animal studies where T-PRF was applied, it was demonstrated that new bone formation could be achieved within 30 days. (Tunalı et al., 2013)

Figure 2. *Glass tube (a), titanium tube (b), and nano-titanium-coated tube (c). (Tunalı M, Ercan E, Pat S, Sarıca E, Bağla AG, Aytürk N, Sıddıkoğlu D, Bilgin V. Nano-titanium coating on glass surface to improve platelet-rich fibrin (PRF) quality. J Mater Sci Mater Med. 2024 Nov 6;35(1):67)*

Advanced Platelet-Rich Fibrin (A-PRF)

By modifying the centrifugation speed (rpm) and duration outside of the standard protocol, the distribution of cellular components can also be altered. (Miron et al., 2017) A-PRF is a new PRF protocol described by Choukroun and colleagues. (Choukroun, 2014) It is obtained by transferring venous blood from the patient into 10 ml tubes without anticoagulant and centrifuging at 1500 rpm for 14 minutes (or 8 minutes for A-PRF+). (Ghanaati et al., 2014; Fujioka-Kobayashi et al., 2017) Studies have shown that platelets tend to decrease in the peripheral portions of standard PRF, while A-PRF exhibits a more even distribution. (Ghanaati et al., 2014) The same study reported that the transformation of neutrophilic granulocytes into monocytes and macrophages plays a significant role in tissue regeneration. In A-PRF, the penetration of neutrophilic granulocytes into the fibrin clot was found to be twice as high compared to PRF. Stem cells, monocytes, and T and B lymphocytes were observed to accumulate in the buffy coat (BC) layer that forms above the red blood cell layer. (Ghanaati et al., 2014)

Injectable Platelet-Rich Fibrin (i-PRF)

Under standard protocols, centrifugation results in the separation of blood into three layers, with red blood cells settling at the bottom. It has been proposed that reducing the centrifugation speed can increase the cellular content of PRF. (Fujioka-Kobayashi et al., 2017) i-PRF is a regenerative agent obtained by transferring venous blood into a specialized tube and centrifuging it at 700 rpm for 3 minutes. (Figure 3) Developed to take advantage of its liquid form, i-PRF has been reported in studies to promote greater cellular migration compared to PRP. (Fujioka-Kobayashi et al., 2017)

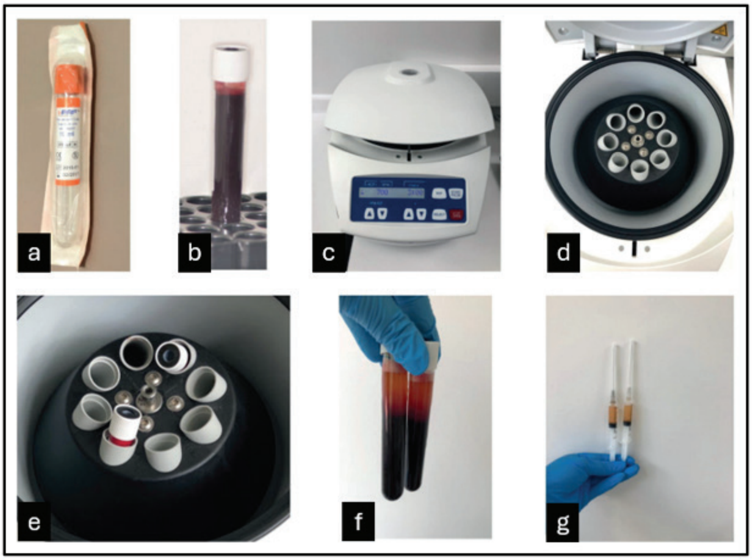

Figure 3. *The preparation process of i-PRF: i-PRF tube (a), venous blood drawn from the patient (b), centrifuge device (c), internal chamber of the centrifuge (d), oppositely placed tubes (e), separation of blood into layers (f), i-PRF aspirated into the syringe (g). (Ozsagir ZB, Tunali M. Injectable platelet-rich fibrin: a new material in medicine and dentistry. Mucosa 2020;3:27-33)*

Albumin Gel and Liquid Platelet-Rich Fibrin (Alb-PRF)

While PRF can be used as a membrane, it tends to resorb faster than desired—typically within 10 to 14 days. (Kawase et al., 2015) To address this limitation, studies have attempted to compress PRF by applying heat, which has shown to extend the resorption time to at least three weeks. In an effort to prolong resorption time without compromising the cellular content of PRF, a new method has been developed. After performing standard centrifugation, the acellular plasma from the topmost portion of the tube is collected using a 2 ml syringe and denatured at 75°C to form albumin. The denatured albumin is then combined with the remaining

PRF to produce Alb-PRF. Alb-PRF has been reported to release growth factors into the surrounding environment at a slower rate. (Fujioka-Kobayashi et al., 2021)

Figure 4. *Evolution of platelet concentrates from past to present.*

	Centrifugation Speed (rpm)	Centrifugation Time (minute)	Type of tube	The structure of PRF
PRF (L - PRF)	2700	12	Glass	Solid
T - PRF	2700	12	Titanium	Solid
A - PRF	1300	14	Glass	Solid
A - PRF+	1300	8	Glass	Solid
i - PRF	700	3	Plastic	Liquid

Table 3. *Types of PRF.*

Clinical Applications of PRF

Mucogingival Surgery

A study assessing the efficacy of platelet-rich fibrin (PRF) in donor site wound healing following free gingival graft (FGG) surgery compared the healing outcomes of a control group (which underwent secondary intention healing) and a test group treated with titanium-prepared PRF (T-PRF). Surface epithelialization was evaluated at 3, 7, 14, and 21 days using the bubble (foam) test, where hydrogen peroxide (H_2O_2) was applied to the wound surface. The results revealed that T-PRF application facilitated earlier epithelialization (Ustaoğlu, Ercan, & Tunali, 2016). In a clinical study by Padma et al. (2013), bilateral Miller Class I and Class II gingival recession defects were treated either with a coronally advanced flap (CAF) alone or in combination with PRF (CAF + PRF). Clinical parameters—clinical attachment level (CAL), width of keratinized gingiva, and recession depth—were measured at 1, 3, and 6 months. The 6-month follow-up demonstrated significantly greater improvements in CAL and keratinized gingival width in the CAF + PRF group compared to the CAF-only group (Padma et al., 2013). A subsequent meta-analysis by the same authors in 2020 on the use of PRF in the treatment of gingival recession confirmed that PRF had a positive impact on mean root coverage, CAL, width of keratinized tissue, and gingival thickness (Panda et al., 2020).

In another clinical investigation, gingival recession defects were treated using a tunnel technique in combination with either a subepithelial connective tissue graft (SCTG) or SCTG + PRF. Forty Miller Class I and II recession defects were evaluated clinically at baseline, day 10, and at 1, 3, and 6 months postoperatively. The outcomes achieved with PRF were comparable to those obtained with SCTG alone, with improved patient comfort reported in the PRF group (Chandra et al., 2022).

Intrabony Defects

In a randomized clinical trial involving 15 intrabony defects, treatment with xenograft alone was compared to xenograft combined with PRF. A statistically significant improvement in clinical attachment level was observed in the PRF group at the 6-month follow-up (Sezgin et al., 2017). Similarly, in a study involving 17 intrabony defects treated with either xenograft alone or xenograft + PRF, the PRF group showed significant reductions in probing depth and increases in bone fill and clinical attachment levels during the follow-up period (Lekovic et al., 2012). In another study, 32 intrabony defects were managed using either open flap debridement (OFD) alone or OFD combined with PRF. Clinical parameters—including probing depth, clinical attachment level, bleeding on probing, plaque index, and gingival margin level—were recorded at baseline and at 9 months postoperatively. The PRF group exhibited superior clinical and radiographic outcomes, including significantly greater bone fill, compared to the OFD-only group (Thorat et al., 2011).

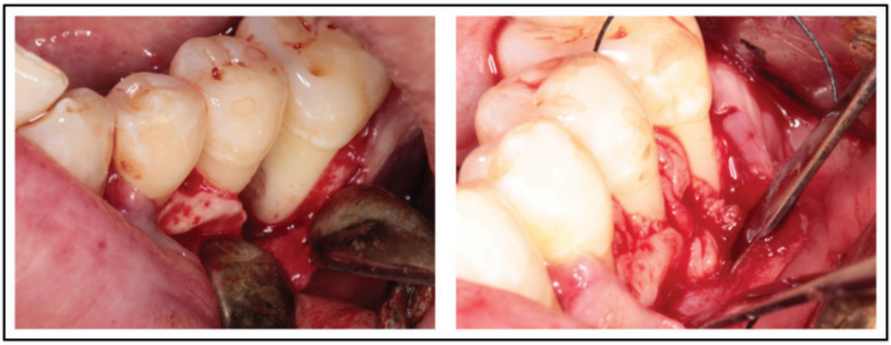

Figure 5. *Application of PRF to an intrabony defect.*

Socket Preservation Applications

In a case scheduled for delayed implant placement, socket preservation was performed using PRF following tooth extraction. A histological evaluation was conducted at the 3rd month, revealing improvements in both hard and soft tissues. (Serafini et al., 2020) In a study involving 20 patients who required third molar extraction, PRF was applied to the extraction sites in the test group, while no additional intervention was performed in the control group. Postoperative pain, soft tissue healing, and newly formed bone trabeculation were evaluated in both groups. The test group exhibited reduced postoperative pain, enhanced soft tissue healing, and earlier trabeculation formation. (Singh, Kohli & Gupta, 2012)

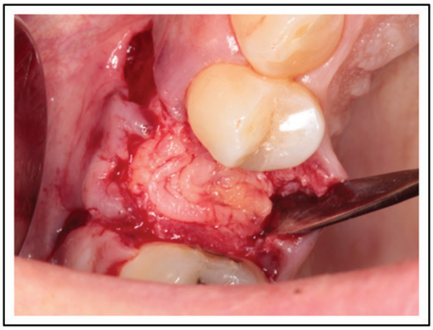

Figure 6. *Use of the L-PRF membrane for socket preservation after extraction.*

Maxillary Sinus Floor Elevation

In a study conducted by Gassling et al. in 2013, patients who were to undergo bilateral sinus lifting prior to implant therapy were treated with autogenous bone grafts and xenografts on one side, while PRF was placed on the other side for sinus elevation. At the 5-month follow-up, tissue samples were collected from both sides using trephine drills for histological evaluation, and similar bone formation was observed. (Gassling et al., 2013) In a sinus lifting procedure performed using the balloon technique, T-PRF and allograft were compared, and it was reported that the newly formed bone and its density were similar in both groups. (Olgun et al., 2018)

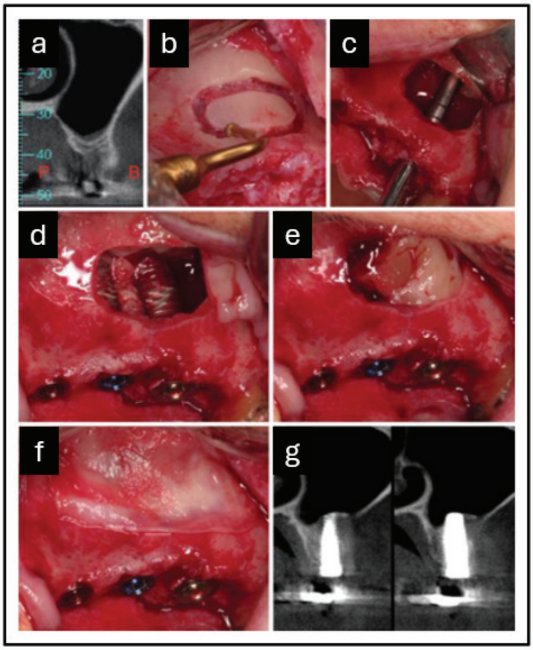

Figure 7. *3D image showing 2 mm residual bone height in the posterior maxilla (a) Osteotomy procedure for lateral window (b) Formation of implant sites and control with osteotome (c) PRF membranes covering the Schneiderian membrane (d) Implants placed, and the membrane served as a tent screw to maintain the elevated position. The cavity was filled with compressed PRF membranes (e) A final PRF membrane used to close the lateral osteotomy window (f) Six months post-surgery, X-ray 3D examination showed that the implants were surrounded by bone-like dense tissue up to the tip of the implant (g). (Mazor Z, Horowitz RA, Del Corso M, Prasad HS, Rohrer MD, Dohan Ehrenfest DM. Sinus floor augmentation with simultaneous implant placement using Choukroun's platelet-rich fibrin as the sole grafting material: a radiologic and histologic study at 6 months. J Periodontol. 2009 Dec;80(12):2056-64)*

Dental Implant Surgery

In a study where implant surgery was planned and the residual bone volume was sufficient, ISQ values were compared between two groups. In one group (socket), PRF was applied, while in the other group it was not. In the PRF-treated group, implant stability was found to be significantly higher at the 1st week and 1st month. (Öncü & Alaaddinoğlu, 2015) In another study, implant placement was performed with the test group receiving implant + PRF, while the control group only received implant placement. Soft tissue around the implant and radiographic bone presence/loss were evaluated at baseline and at the 3-month postoperative period. The authors reported less marginal bone change in the PRF-treated group. (Boora, Rathee, & Bhoria, 2015)

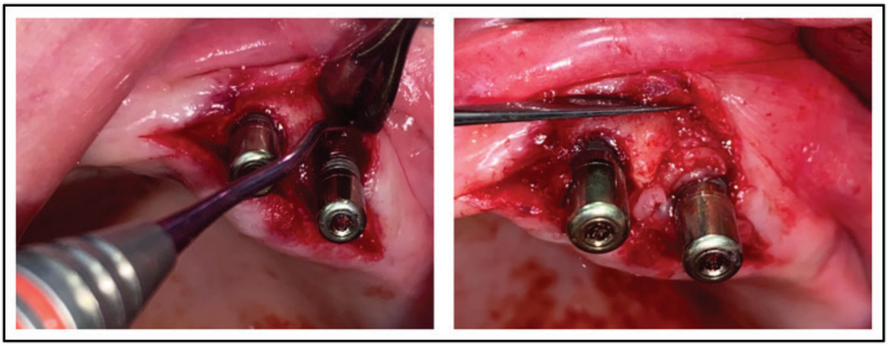

Figure 8. *The application of PRF in the management of peri-implant bone defects.*

Cystic Lesions and Furcation Defects

In a study conducted by Dar et al. in 2016, new bone formation was observed at the postoperative 6-month period after PRF application in areas where cystic lesions were detected and enucleated. (Dar et al., 2016) In a different study, after the enucleation of a cystic lesion, PRF was applied and controls were performed at 1, 3, and 6 months. Bone filling was observed at the 6-month mark. (Meshram et al., 2015) In a meta-analysis evaluating the effectiveness of PRF, it was reported that the use of graft + PRF in teeth with Class II furcation problems resulted in clinical attachment gain and increased the level. (Tarallo et al., 2020) In a study by Sharma et al. in 2011, open flap debridement and open flap debridement + PRF were applied in Class II furcation problems, and clinical parameters (bleeding and plaque index, probing depth, and clinical attachment level) were recorded at baseline and at the postoperative 9-month period. Statistically significant differences in clinical parameters and radiographic bone fill were observed in the PRF-treated group. (Sharma & Pradeep, 2011) In another study treating Class II furcation defects, only mandibular molars were included. Treatment was applied in three groups: (I) open flap debridement, (II) open flap debridement + PRP, and (III) open flap debridement + PRF. Clinical parameters and radiographic images were recorded at baseline and at the 9-month postoperative period. Clinical attachment gain was found to be statistically significantly higher in the groups where platelet concentrates (PRP - PRF) were applied. It was concluded that platelet concentrates are effective in the treatment of furcation defects and in preventing possible complications. (Bajaj et al., 2013)

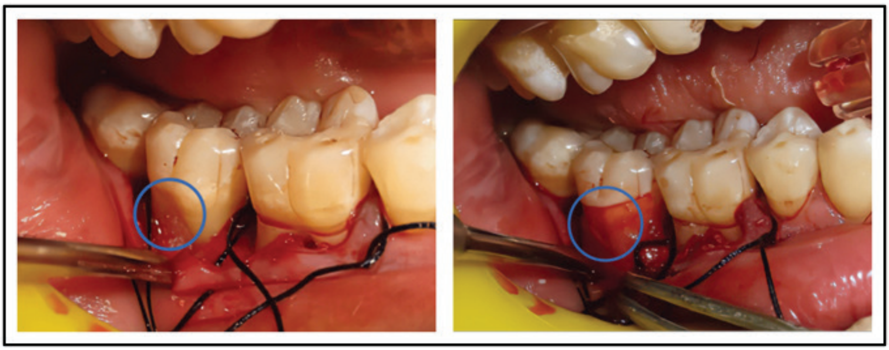

Figure 9. *The application of PRF in the treatment of furcation defects. (Patel B, Joshi S, Nagrani T, Girdhar GA, Patel H, Sinha S, Haque M, Kumar S, Haq MA. Clinical and Radiographic Evaluation of Autologous Platelet-Rich Fibrin With or Without Demineralized Bone Matrix in the Treatment of Grade II Furcation Defects. Cureus. 2023 Aug 30;15(8):e44394)*

Applications in Orthodontics, Pedodontics, and Endodontics

In a study evaluating extraction sockets, one group was treated with PRF, while the other group was left to heal naturally. The PRF-treated group showed better bone filling and faster orthodontic tooth movement. (Nemtoi et al., 2018) In a similar study, faster orthodontic tooth movements were also observed in the group treated with PRF. (Tehranchi et al., 2018) In a study where PRF was placed at the apex, a decrease in the radiolucent area was observed during the 6-month and 2-year follow-up. (Yadav et al., 2015) A meta-analysis reported that platelet concentrates can be used in pulp capping treatments, pulpectomies, and apexogenesis due to their positive effects on pulp tissues. (Nagar and Viswanath, 2012)

In a 12-month study where platelet concentrates (PRP and PRF) were used with MTA for pulp capping, dentin bridge formation was significantly higher in the PRP and PRF groups compared to MTA, and these groups also showed positive pulp vitality test results. (Shobana, Kavitha, and Srinivasan, 2022) A meta-analysis of 12 studies on endodontic regeneration found that PRF was more successful than the apical bleeding technique in terms of apical closure and root wall thickening. (Murray, 2018)

Temporomandibular Joint (TMJ) Applications

In a study by Işık et al. in 2022, the pain levels of patients treated with arthrocentesis and arthrocentesis + i-PRF were evaluated at 1, 2, 3, 6, and 12 months. The i-PRF group showed reduced pain and improved functional limitations. (Işık et al., 2022) In another study, treatment groups included arthrocentesis, hyaluronic acid + i-PRF, and i-PRF alone. Pain and mouth opening were evaluated, and the authors reported that i-PRF had positive effects on reducing pain and increasing mouth opening. (Yuce and Komerik, 2020)

Conclusion

Platelet-rich products demonstrate regenerative and immunological effects through their growth factors, cytokines, and cells. They increase vascularization in the treated areas, positively influencing tissue healing. The ease and speed of preparation before or during the procedure help save time and provide benefits in clinical applications. Additionally, since these products are derived from the patient's own blood, they eliminate the risk of disease transmission, do not cause side effects, and reduce costs. In dental practice, these products are safely applied in many areas with successful outcomes. With new research, the mechanisms of action of these products can be better understood, and their range of applications can be expanded.

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Chapter 3

CURRENT DEVELOPMENTS IN GLASS IONOMER CEMENTS

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With changes in patient demands and professional perceptions in dentistry, there has been continuous progression in innovations. Developments in adhesive technology have come to the forefront in protective and preventative treatments (Hickel, Manhart, & García-Godoy, 2000). There has also started to be awareness of new materials with the adoption of the greater importance of biocompatibility and the prioritisation of more invasive techniques to protect healthy tissues in caries treatment. The main demands of patients today in dentistry are based on aesthetics, biocompatibility, and low cost. Restorative dentistry, which started with amalgam restorations, has continued by changing to composites because of the serious concerns raised about aesthetics and biocompatibility. Amalgam, composite, and glass ionomers are the three basic materials used directly in restoration structures. When the use of these in other countries is examined, there can be seen to be increasing interest in aesthetic materials (Davidson, 2003).

Of the most important reasons for changing dental restorations, the main reason is the formation of caries. The first route to preventing caries is to select material with the property of fluoride release. The effect mechanism of fluoride is that remineralisation is provided by the formation of fluorapatite and demineralisation is reduced by preventing the proliferation of microorganisms (Arisu, 2007).

Glass ionomer cements, developed by Wilson and Kent in 1972, have become the leading materials in modern dentistry. The primary components, fluoro-alumino silicate glass and polyacrylic acid, constitute the general name of glass ionomer cements.Glass ionomer cements, which are produced to benefit from the advantages of both silicate cement and polycarboxylate cement, are obtained by mixing powder and liquid forms (Alla, 2013; Sita Ramaraju, Alla, Alluri, & Raju, 2014). The hardening reaction occurs with an acid-base reaction in full or one part. One of the most important properties of glass ionomer cements is the ability to release fluoride and to be used as a fluoride reservoir (Kanık and Türkün, 2016).

The hardening reaction occurs in four stages. First, there is dispersion of glass particles within the polycarboxylate acid solution. The acid attack formed on the surface with the combination of powder and liquid causes breakdown of the glass particles and this releases Ca^{+2}, Na^{+1}, and Al^{+3} ions. In the second stage, a silica hydrogel layer forms on the surface of the glass particles, and this layer is enriched by the Ca^{+2} and $A1^{+3}$ ions in the cement structure. At this stage where cement is affected by moisture, if there is contact with water the cement will not harden sufficiently, thereby making it less resistant. The third stage is the hardening phase, when the resistance of the insoluble material of the metal ions increases. The fourth and final stage in which the binding force is increased is the maturation stage which continues for several months (Peker and Bolgül, 2023).

Glass ionomer cements have many advantages such as the ability to chemically bind to dental tissues, not requiring any adhesive agent at the binding stage, the ability to provide good adaptation to body tissues with no allergic reactions (biocompatibility), being of dental colour, the thermal expansion coefficient being compatible with the tooth, high resistance to acid and mechanical stress, exhibiting anticariogenic properties as it is a source of fluoride, low cytotoxicity, and microleakage at a minimum level (Wiegand, Buchalla, & Attin, 2007). However, in addition to these advantages, there are also the disadvantages of a short working time, high sensitivity to moisture, a long hardening time, low resistance to wear and pressure, unsustainable aesthetics as the colour deteriorates over time, and weak physical and mechanical properties (Kaya and Tirali, 2013).

Glass ionomer cements, which have a wide area of use in clinical dentistry, are used as the base material or temporary filling material in filling construction, in root surface caries, in the adhesion of prosthetic crown bridges, and bands and brackets in orthodontics, in the cementation of fixed space maintenance, and especially in individuals with a high potential for caries. The preparation of this material, which is often used in respect of patient comfort, is extremely simple (Khalilova, 2024).

Glass ionomer cements have strong mechanical properties, are preferred for long-lasting fillings, and have been designed with specific properties to undertake different tasks in dentistry. There are various classifications related to these. According to the form of use, there are three types; type I: for adhesive purposes, type II: for restorative purposes (aesthetic, strengthened, high viscosity), type III: used as rapidly hardening base material and fissure coverage (Kaya and Tirali, 2013). According to content, they can be classified as traditional glass ionomer cements, polyacid modified composite resins (compomers), high-viscosity glass ionomer cements, giomers, and nano-ionomers (Elaci and Tunçdemir, 2020). According to hardening reactions, they are separated into three groups as traditional glass ionomer cements, resin-modified glass ionomer cements, and polyacid-modified composite resins.

Recent research has been directed towards improving aesthetics and increasing resistance to mechanical stress. The disadvantages of glass ionomer cements have decreased with advances in technology (Khalilova, 2024). Patients particularly wish to have teeth with a good aesthetic appearance; therefore, the development of aesthetically better glass ionomer cements will increase patient trust. In this respect there has been an increase in the concept of reinforced glass ionomer cements. Metal particles, glass fibers, and ceramics have been used for structural improvement. Encouraging results have been obtained particularly with the addition of reactive glass fibres (Williams, Billington, & Pearson, 1998).

Traditional Glass Ionomer Cements

This cement, which is made by mixing powder and liquid, consists of a polymer matrix that is formed by the cross-linking of fluoro-alumino-silicate particles and ions (Lohbauer, 2009). Polycarboxylic acids form the matrix part of glass ionomer cements. These acids can change the properties of glass ionomers. Polyacids are able to bind to metals and dental tissues without any need for surface preparation, even in the presence of moisture (Baelum, Fejerskov, & Nyvad, 2008). When there is low resistance to wear and solubility of this material, which has great sensitivity to moisture in the hardening reaction, the restoration will be unsuccessful. The sensitivity to moisture continues until completion of the hardening reaction (Kleverlaan et al., 2004).

Traditional glass ionomer cements are usually used as base material. As this material can cross-link with calcium ions in the tooth it has the property of being able to make direct adhesion (Elmaci and Tunçdemir, 2020). There is fluoro-alumino-silicate polycarboxylic acid, glass, water, and tartaric acid in the content. To be able to obtain opacity on dental radiographs, substances such as barium, strontium, and lanthanum should be placed within the glass powder (Baig and Fleming, 2015).

For glass ionomer cements to function as a reservoir, fluoride is added to the structure. Similarly, the addition of hydroxyapatite, fiber, metal, and bioactive glass particles increases the resistance, hardness, and antimicrobial efficacy of these cements (Nezir and Özcan, 2022). To further improve the physical and mechanical properties of these cements, resin has been added to the material, and thus resin-modified glass ionomer cements have been obtained (Sidhu, 2010).

In a previous study that compared the clinical lifetimes of amalgam, composite, and glass ionomer cements, lower results were observed for glass ionomer cements (Kim, Namgung, & Cho, 2013).

Resin-Modified Glass Ionomer Cements (RMGIC)

RMGIC, also known as a hybrid or light-cured glass ionomer, was developed by Antonucci et al. in the 1980s. These cements are formed as a compound of 80% glass ionomer cement and 20% resin and were developed to overcome the deficiencies in moisture sensitivity and physical properties of traditional glass ionomer cements (Mount, 2001).

It was also aimed to preserve the basic properties specific to glass ionomer cements such as fluoride release, chemical adhesion, and recharging (Torabzadeh, Ghasemi, Shakeri, Baghban, & Razmavar, 2011; Welbury, Duggal, & Hosey, 2018). The chemical binding between the resin and glass particles in the content of these cements provides a significant improvement in tensile and bending strengths compared to traditional glass ionomer cements by increasing the mechanical performance of these materials (Nezir and Özcan, 2022). They are also biocompatible, easy to apply, have a long working time, good surface hardness, low solubility in oral tissues, and hydrophilic properties (Croll and Helpin, 1995; Croll and Nicholson, 2002).

The powder part of this type of cement is formed of fluoro-alumino-silicate glass particles, and the liquid part is formed of HEMA, methacrylate groups, tartaric and polyacrylic acid, and 8% water. The hardening reaction is first acid-base and secondly photochemical polymerisation (Sidhu and Watson, 1995). The acid-base reactions that occur after photopolymerisation significantly improve the mechanical properties by providing full hardening of the material. As a result of polymerisation there may be residual monomer release and this can cause adverse effects such as sensitivity or inflammation in the pulp. There may also be side-effects such as allergic reaction and contact dermatitis (Kanik and Türkün, 2016). Even if there is very good polymerisation, there may be residual monomer (HEMA) release (Nicholson and Czarnecka, 2008).

When evaluated in respect of disadvantages, there is a higher probability of microleakage due to polymerisation shrinkage, a high probability of stress formation in tissues surrounding the tooth as hardening is quicker and binding to dental tissues is not as good as in traditional glass ionomers, and the rate of fluoride release is low (Altan, 2013).

There is greater binding to enamel than dentin in resin-modified glass ionomer cements. Within approximately 15 minutes, 80% resistance is reached and within a few days this binding resistance reaches values as high as 2.6-9.6 MPa. Although these values are high failure is generally in the form of breakage within the cement (cohesive fracture) and does not reflect the real adhesive strength (Sidhu and Nicholson, 2016).

Polyacid-Modified Composite Resin (Compomers)

In 1994, in order to benefit from the advantages of composites and glass ionomers, compomers were produced, consisting of 30% glass ionomer cement and 70% composite resin; dimethacrylate monomers with two carboxyl groups and ion-releasing glass-like fillers found in traditional glass ionomers (Uzel, 2012). The content is not limited to these but also contains reaction starters, stabilisers, and pigments. In this material with a single component structure, the hardening mechanism is provided with light. When there is contact with saliva after polymerisation, the acid-base reaction starts (Karakaş, 2022). Fluoride release is extremely low because the glass ionomer content is low. As the resin content increases, they exhibit properties similar to those of composites (Hes, 1999).

In a clinical study with a 2-year follow-up period by Türkün and Çelik, compomer restorations used in Class V lesions were reported to be successful at the rate of 96%, and it was emphasized that these materials were superior to composite resin restorations in terms of colour compatibility (Türkün and Çelik, 2008). In another study, a composite resin and two different compomers were evaluated at the end of 24 months, and compomers, especially in Class I and II restorations, were found to provide the most clinically successful results (Pascon et al., 2006).

As compomer materials are not water-based structures, the acid-base reaction typically observed in traditional glass ionomer cement does not occur in this material. Therefore, it is not a correct approach to fully include compomers in the classic glass ionomer cement category. Acid-base interaction can only start in a moist environment within the mouth and which allows the material to be able to release fluoride (Mahoney, 2013). Various studies have shown that the fluoride release capacity of compomer materials is lower than both traditional glass ionomer cements and resin-modified glass ionomers.This is thought to be due to the fluoride ions in the compomer structure binding to the filler particles before contact with liquid in the oral environment (Wiegand et al., 2007; Dionysopoulos, Kotsanos, & Pataridou, 2003; Attar and Turgut, 2003).

Although compomers have more superior properties of microhardness and resistance to pressure compared to glass ionomer cements, they are lower than composites. However, when evaluated with respect to the surface roughness, no difference was observed between the two materials (Mittal and Gupta, 2021).

Giomers

Giomers, which can be bound to dental hard tissues with the help of a bonding agent, contain the superior properties of composite resins with glass ionomers that release fluoride, thereby offering the advantages of light-curing, aesthetic appearance, mechanical resistance, and the ability to be well polished (Najma Hajira and Meena, 2015). However, the potential for water abbsorption and discolouration is higher than that of composite resins (Elmavi and Tunçdemir, 2020). Although giomer is better than compomer in respect of fluoride release, it is relatively lower than traditional and resin-modified glass ionomers (Bansal and Bansal, 2014).

Giomers are a recently developed hybrid material containing reactive glass particles (Çapan and Akyüz, 2016). The formation of these particles, which function in the release of fluoride is based on the acid-base reaction of polyalkenoic acid with fluoro-alumino-silicate glass particles, which occurs in the liquid environment (Nezir and Özcan, 2022).

This material has similar clinical indications to that of traditional glass ionomer cement, and is used as cavity floor material, as fissure coverage, in restorations of milk teeth and root caries, and in cervical erosion (Rusnac et al., 2019; Abdel-Karim, El-Eraky, & Etman, 2014). A study conducted on Class II cavities used giomer, resin-modified glass ionomer, and compomer hybrid composites. According to the 2-year follow-up results of that study, restorations made with giomer material showed long-term resistance and achieved clinical success at the rate of 79% (Sengul and Gurbuz, 2015). In another study conducted on restorations of cervical lesions without caries, the bonding capacity of giomers with dentin was similar to that of resin-modified glass ionomer cements, but giomers were reported to show significantly better performance in respect of surface roughness (Jyothi, Annapurna, Kumar, Venugopal, & Jayashankara, 2011).

High-Viscosity Glass Ionomer Cement

These cements were developed in 1995 for use in atraumatic restorative treatment, and are obtained with the addition of polyacrylic acid to high-viscosity powder. Compared to traditional glass ionomer cements, there is lower resistance to abrasion, wear, and tension, the indication area is broader, and solubility and sensitivity to moisture are lower. Biocompatibility, fluoride release, and hardening mechanisms are similar to those of traditional glass ionomer cement (Basting, Serra, & Rodrigues, 2002; Dowling and Fleming, 2009). Another aim in the production of this cement was to create an alternative to amalgam and composite in restorations. In a study of 750 teeth by Hilgert et al., in which the clinical success of HVGIC was evaluated, no significant difference was observed, which was interpreted as an indicator that this type of cement could be a good alternative in permanent restorations (Hilgert et al., 2014).

These cements harden with an acid-base reaction as in traditional glass ionomer cement, but in contrast, disadvantages specific to the material such as moisture sensitivity encountered in the early stage due to the characteristic of rapid hardening, have been shown to be largely eliminated (Çapan and Akyüz, 2016). The manufacturing firms recommend the use of surface protective resin to improve the physical and mechanical properties of the material. Thus the brightness of the material is increased and surface irregularities are eliminated (Kütük, Gürgan, Çakır, Ergin, & Öztaş, (2014).

Capsular forms have been developed to be able to provide ease-of-use, adjustment of the high powder-liquid ratio, and appropriate texture and homogeneity. The porosity formed in manual mixing is relatively higher than that of the capsule forms, because the powder-liquid ratio cannot be correctly adjusted. Porosity formed during the mixing significantly reduces the resistance of the cement (Guggenberger, May, & Stefan, 1998).

Glass Carbomer Cement

This is a type of cement containing fluoroapatite and nanoparticles, which provides remineralisation of dental tissues through fluoride release. It is often preferred in paediatric dentstry. The presence of nanoparticles allows this material to be resistant to wear and develop mechanical properties (Cehreli, Ebru, Yalcinkaya, & Cehreli, 2013). One of the most important advantages is that it is not moisture sensitive and retains its applicability even when there is insufficient isolation (Subramaniam, Girish Babu, & Jayasurya, 2015).

This type of cement hardens chemically, with no requirement for any adhesive for cement-tooth bonding. It can be used in areas that do not have indications for glass ionomer cements (Dülgergil and Ertürk, 2016).

Conclusion

In conclusion, glass ionomer cements have an important place, especially in restorative and preventative dentistry, and are currently frequently used because they are biocompatible materials that can release fluoride and have a broad area of indications. There is ongoing research to create an alternative to composite and amalgam.

Together with future developments in technology, more effective use of glass ionomer cement is expected and this should be supported with further studies.

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Chapter 4

NON-CARIOUS CERVICAL LESIONS (NCCLS)

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As societies become increasingly socialized and daily life grows more demanding, concerns related to both aesthetics and health have become more prominent among individuals. From a dental perspective, these developments have led to heightened attention toward maintaining both general and oral health. However, it has been well-documented that the materials used, dietary patterns followed, and procedures driven by aesthetic concerns may lead to varying degrees of hard tissue loss in teeth.

A common manifestation of such tissue loss is observed in the cervical region of the tooth, where lesions not associated with carious microorganisms are frequently identified. These conditions are referred to in the literature as Non-Carious Cervical Lesions (NCCLs) or collectively as tooth wear.(Grippo, 1991) Etiologically, tooth wear is examined under four principal categories—abrasion, attrition, erosion, and abfraction—based on the underlying mechanisms responsible for the progressive loss of dental hard tissues from past to present.

Abrasion

The term *abrasion* originates from Latin, derived from words such as *abrasum*, which refers to the scraping or wearing away of a surface by an external agent. In English dental literature, "abrasion" is the direct equivalent of this concept. When applied in dentistry, it describes a pathological interaction in which a foreign object, rather than another tooth, physically rubs against the tooth surface, causing non-carious loss of hard dental tissues.(D. W. Bartlett & Shah, 2006; Grippo, 1991)

In short, abrasion-related tooth wear refers to the mechanical removal of dental hard tissue caused by a foreign substance, rather than by tooth-to-tooth contact. When evaluating the causes of abrasions, especially those identified as abrasion-induced, one of the most significant contributing factors is oral hygiene behavior.

When oral hygiene habits are examined, abrasion is most frequently observed on premolars and canines, followed by molars and incisors, depending on brushing technique and frequency. Clinically, early-stage abrasions appear as horizontal white striations along the cervical margins of the affected teeth. In more advanced cases, particularly when dentin is involved, smooth and shiny areas of tissue loss are most often seen on the vestibular surfaces of these teeth.(Schmidt & Watson, 2019) Such patterns of abrasion are commonly found in individuals who place a high priority on oral health and aesthetics, especially those dissatisfied with the color of their teeth.

Individuals who brush their teeth twice or more per day tend to exhibit a higher incidence of abrasion compared to those who brush less frequently.(Saxton & Cowell, 1981) Tooth wear is particularly prominent on the surfaces of canines and premolars—especially in the region where brushing typically begins. These teeth are thought to be more susceptible due to the initial force applied at the start of brushing.(Litonjua et al., 2003)

Moreover, the pattern of abrasion often varies depending on hand dominance. In right-handed individuals, abrasion-related wear is more commonly observed on the left side of the dental arch, whereas in left-handed individuals, the right side is more frequently affected. This distribution is attributed to the direction and pressure of the brushing motion.(Levitch et al., 1994)

The type of toothbrush used, the structure of its bristles, and the materials contained in the toothpaste have all been reported as contributing factors to dental abrasion. The thickness, stiffness, density, arrangement of the bristle tufts, and their ability to retain and distribute toothpaste play a significant role in the extent of tooth surface wear.

While numerous studies have demonstrated that hard-bristled toothbrushes contribute to abrasion, it has also been shown that even soft-bristled brushes can produce abrasive effects when used with excessive brushing force.(González-Cabezas et al., 2013)

In individuals using removable prostheses, abrasion caused by clasps—the retentive components of the prosthesis—is frequently observed. Such types of tooth wear are fundamentally multifactorial in nature. Additionally, abrasion may occur due to occupational factors or parafunctional habits.

For instance, individuals who habitually hold objects such as string, needles, nails, or similar materials between their teeth as part of their profession often exhibit abrasion on the incisal edges of the anterior teeth, particularly the incisors.

Attrition

The term *attrition* is derived from the Latin word *attritum*, which refers to the friction between two similar surfaces. In dentistry, *attrition* describes the loss of dental hard tissue that occurs due to the contact and friction between opposing tooth surfaces during functions such as chewing and biting. Unlike other types of tooth wear, attrition does not involve any foreign object; the tissue loss results purely from tooth-to-tooth contact.(D. W. Bartlett & Shah, 2006; Grippo et al., 2004)

Although attrition is often described as an age-related process, the dental literature distinguishes between two different types of attrition.

The first is physiological attrition, which develops naturally over time as teeth are used throughout a person's life. Attrition-related tissue loss typically affects the occlusal, incisal, and palatal surfaces of the teeth, where direct contact between opposing teeth occurs.(Imfeld, 1996a)

Depending on the severity of the case, the occlusal surfaces may show worn-down cusps, while the incisal edges and palatal surfaces of the upper anterior teeth may appear scooped out. In advanced cases, enamel loss may be complete, and even dentin may be worn down to the level of the pulp chamber. Severe attrition can result in a reduced vertical dimension of occlusion, leading to both esthetic concerns and temporomandibular joint (TMJ) issues.(Bishop et al., 1997)

In cases of advanced attrition where dentin is exposed, dark discoloration caused by external factors may be observed—particularly in the lower incisors, where a circular, darkened area often appears at the center of the incisal edge. Physiological attrition can also affect approximal surfaces, which may contribute to natural mesial drift of the teeth over time. (Bishop et al., 1997)

Another dimension of attrition is referred to as pathological attrition, which is not age-related but rather associated with parafunctional habits such as teeth clenching and bruxism. Bruxism, in particular, involves involuntary contact between opposing teeth outside of normal chewing function. This condition is frequently observed in individuals under high stress and is especially prevalent among young adults. Studies have reported that it occurs more commonly in males than in females.

In addition, individuals using ill-fitting prostheses have also been reported to develop clenching and grinding habits. Over time, these parafunctional behaviors can lead to temporomandibular joint (TMJ) disorders, and the progressive pathological wear may result in facial changes that give the individual an unhealthy or prematurely aged appearance. (Kaushik et al., 2009)(Yadav, 2011)

Pathological attrition has also been observed in individuals with dental anomalies such as amelogenesis imperfecta and dentinogenesis imperfecta, as well as in patients with malocclusion and premature occlusal contacts due to misaligned teeth.(Yadav, 2011)

Erosion

The term *erosion* originates from the Latin word *erodere*, meaning "to decay" or "to wear away," and entered the Turkish language via the French term *érosion*. In dentistry, dental erosion refers to the loss of hard dental tissue caused by chemical processes without the involvement of caries-producing bacterial activity.(Lussi & Ganss, 2014)

In erosive wear, the acids responsible are not those secreted by cariogenic bacteria. In fact, *Streptococcus mutans*, the primary bacterium associated with caries, cannot survive at the low pH levels that lead to enamel erosion.(Meurman & ten Cate, 1996) However, erosion is not a purely acid-driven phenomenon; rather, it is a multifactorial process. Once acids soften the enamel surface, other factors—such as chewing forces, occlusal patterns, frequency and force of tooth brushing, parafunctional habits, and additional contributing elements—combine to accelerate tissue loss.(Lussi, 2006)

Erosive lesions are most commonly observed on the labial surfaces of the upper incisors and the buccal surfaces of the lower incisors, and may cause these areas to appear more translucent. They are less frequently found on approximal surfaces and generally appear symmetrically across both dental arches. As erosion progresses and reaches the dentin layer, tooth sensitivity may develop. Once dentin is exposed, the progression of erosion accelerates.

In patients with amalgam restorations, erosion can lead to the surrounding tooth structure wearing away, making the restoration appear elevated above the tooth surface. As enamel softens due to acid exposure, affected teeth become more vulnerable to abrasion and attrition, especially during chewing or brushing. Clinically, this can result in rounded cusps, reduced crown height, and general tooth shortening.

Patients with erosive lesions often present to dental clinics with complaints such as: sensitivity to hot or cold stimuli, a sharp or tingling sensation when consuming acidic or sweet foods, pain or discomfort during brushing (especially over the affected areas), rough or pitted surfaces on the teeth, and discoloration, with teeth appearing yellow to orange in tone.(Lussi, 2006)

In the literature, dental erosion is categorized based on etiology into two main groups:

– Intrinsic factors (e.g., gastric acid from reflux or vomiting)

– Extrinsic factors (e.g., dietary acids, medications, environmental exposure)

Intrinsic Factors

This category includes various conditions, pathological disorders, physiological processes, or harmful habits that lower the intraoral pH, initially causing softening of dental hard tissues. When additional mechanical or behavioral factors are also present, this leads to progressive tooth wear. Such intrinsic factors typically involve acid exposure originating from within the body.

Examples include gastroesophageal reflux disease (GERD), bulimia (e.g., anorexia nervosa), pregnancy-related vomiting, chronic alcoholism, and Sjögren's syndrome.(Scheutzel, 1996)

In these cases, acids such as gastric hydrochloric acid can lead to enamel demineralization, making the teeth more susceptible to further chemical or mechanical damage.

Extrinsic Factors

In modern society, individuals are increasingly exposed to extrinsic acids through their dietary habits, medical treatments, and occupational environments. The frequent consumption of processed foods and beverages containing acidic preservatives, as well as the use of certain medications required for maintaining systemic health, can contribute to the development of erosive lesions on tooth surfaces.

Additionally, people who work in environments where they are exposed to acidic vapors or liquid acids are also at risk of experiencing externally induced dental erosion. Such exposures can lower the pH in the oral cavity and lead to progressive enamel dissolution over time.

Abfraction

Abfraction lesions are a type of non-carious cervical tooth wear caused by biomechanical forces, particularly those acting along the vertical axis of the tooth. These forces lead to micro-flexure of the tooth at its cervical region, which is considered one of the thinnest and most vulnerable areas of enamel. As the tooth undergoes repeated flexion, microfractures occur at the enamel–dentin interface, ultimately causing the loss of mineralized tissue.

To explain this process in biomechanical terms, when vertical occlusal forces are applied to a tooth, it may exhibit lateral or axial bending. This flexure results in stress concentration, especially at the cervical margins, leading to the disruption of the bonds between hydroxyapatite crystals, and the formation of microcracks in both enamel and supporting dentin.

Parafunctional habits such as bruxism (teeth grinding) and clenching, premature occlusal contacts, eccentric loading, and strong occlusal forces during mastication and swallowing are considered major internal stressors that contribute to abfraction-type lesions.

The frequent consumption of foods that require intense chewing forces, as well as habits such as pipe smoking, chewing on pen tips, or nail biting, are recognized as contributing factors to abfraction lesions due to the external stress they exert on teeth.

In addition, the forces applied by certain orthodontic appliances and retentive components of removable prostheses can also induce localized stress on dental structures. These mechanical stresses, especially when repetitive or sustained, may promote the development of non-carious cervical lesions characteristic of abfraction.(Tomer AK, Miglani A, Sagarika M.2016)

Clinical Classification

While etiological classification plays an important role in understanding tooth wear and is particularly valuable in guiding preventive strategies, it is the clinical classification that becomes more relevant during treatment planning. Clinical classification provides a framework for assessing the severity and extent of lesions, enabling clinicians to select the most appropriate treatment procedures and restorative materials when patients present with tooth wear.(Loomba et al., 2014)

In clinical practice, lesions are evaluated based on three main parameters:

- The depth of the lesion on the axial wall (D),
- The occluso-gingival width of the lesion (G), and
- The angle (A) formed between the lesion walls.

This classification helps practitioners to standardize diagnosis, estimate progression, and make evidence-based decisions regarding therapeutic interventions.

Lesion Depth

Tooth wear lesions are clinically classified into three stages based on their depth, which is typically measured in the buccolingual direction using a periodontal probe equipped with a rubber stopper. The depth of these lesions varies depending on the etiological factors previously described.(D. W. Bartlett & Shah, 2006; Nascimento et al., 2016)(Loomba et al., 2014)

1. Lesions with a depth ≤ 1 mm – D1 (Superficial Lesions)

In these cases, if the width is ≤ 0.5 mm, patients usually do not report sensitivity. When the width exceeds 0.5 mm, desensitizing treatments may be recommended to reduce discomfort and prevent lesion progression. These include fluoride varnishes, CPP-ACP (casein phosphopeptide-amorphous calcium phosphate), or other desensitizing agents. (Loomba et al., 2014)

If the lesion width is greater than 1 mm and esthetic concerns are also present, restorative treatment may involve materials such as glass ionomer cements or flowable composite resins to address both functional and cosmetic complaints.(Bader et al., 1993; Loomba et al., 2014)

2. Lesions with a depth of 1–2 mm – D2 (Moderate Lesions)

These lesions may cause discomfort in response to sweet, cold, or air stimuli. However, in some cases, the formation of sclerotic dentin, which occludes dentinal tubules, may reduce sensitivity.

For D2 lesions, it is recommended to roughen the surface before placing a restoration, as sclerotic dentin can compromise the adhesion of restorative materials. Treatment options may include a glass ionomer base or flowable composites to function as stress-absorbing liners. Alternatively, the cavity can be restored directly using glass ionomer cement, flowable composite, or conventional composite resin without the use of a liner. (Francisconi et al., 2009; Loomba et al., 2014)

3. Lesions with a depth > 2 mm – D3 (Advanced Lesions)

Patients with D3 lesions typically present with pain or significant sensitivity. In some cases, depending on the etiology, the lesion may extend as deep as the pulp. When cavitation approaches the pulp chamber, the use of calcium-containing liners is advised to protect the pulp.

Following pulp protection, the cavity may be restored using resin-modified glass ionomer cements or esthetic composite resins, applied with the aid of dentin bonding agents. In lesions of extreme depth, root canal treatment may be necessary. In advanced cases, this may subsequently require an indirect prosthetic restoration to restore function and esthetics.(Loomba et al., 2014)

Lesion Width

The occluso-gingival distance of a cavity formed as a result of abrasive materials or external forces interacting with the tooth surface defines the width of the lesion. In simple terms, this refers to the vertical distance between the gingival and occlusal margins of the lesion.(Loomba et al., 2014)

Lesions caused by toothbrush abrasion often exhibit greater width and depth on anterior teeth compared to posterior teeth. In cases related to gastrointestinal disorders, broad lesions may appear on the palatal surfaces of upper anterior teeth and the occlusal surfaces of posterior teeth, depending on the area affected by acid exposure.(Amaechi, 2015; D. Bartlett & Smith, 1996)

1. Lesions with width ≤ 1 mm – G1 (Superficial Lesions)

In this classification system, both depth and width are significant parameters. When a lesion is superficial in both dimensions, it can typically be treated effectively with desensitizing agents or remineralizing materials. In cases where the depth increases while the width remains ≤ 1 mm, glass ionomer cements or composite resins may be required to complete the treatment.(Loomba et al., 2014)

2. Lesions with width between 1–2 mm – G2 (Moderate Lesions)

Compared to superficial lesions, moderate-width lesions often require a more advanced restorative approach. The use of adhesive restorative materials is typically recommended to ensure proper function, durability, and esthetics.

3. Lesions with width > 2 mm – G3 (Advanced Lesions)

When the width of a wear lesion exceeds 2 mm, additional clinical measures are often necessary to enhance retention and longevity of the restoration. This may involve surface roughening or creating retentive grooves in the dentin prior to placement of restorative materials.

In cases where both depth and occluso-gingival width exceed 2 mm—especially when the lesion extends subgingivally—periodontal open-flap surgery may be required before restorative treatment can be successfully completed.

For such subgingival lesions, restorative materials with good periodontal compatibility, such as glass ionomer cements or compomers, are typically preferred. These materials offer favorable marginal adaptation and biocompatibility within the gingival environment.(Loomba et al., 2014)

Lesion Angle

The angle of a tooth wear lesion is defined as the angle formed between the occlusal and cervical walls of the lesion. Deeper lesions tend to present with narrower internal angles compared to more shallow, broad-surfaced lesions such as those caused by erosion. For instance, lesions of abfraction and abrasion etiology are typically associated with sharper angles than those caused by erosion.

To measure the lesion angle, an orthodontic wire can be adapted to the internal walls of the cavity, and the resulting configuration can be assessed using a goniometer. Lesion angles can be categorized into three morphological types based on a vertical buccolingual cross-section of the cavity.(Loomba et al., 2014)

1. Wedge-Shaped, Narrow-Angle Lesions (<90°) – A1

These types of lesions are frequently observed in teeth with occlusal interference, premature contacts, or malocclusion-related stress, where occlusal forces cause tooth flexure and shearing stresses, leading to cervical enamel fractures.

In restorations involving such deep wedge-shaped lesions, stress-absorbing materials like glass ionomer cements or flowable composite resins are recommended at the cavity base. These materials help mitigate the risk of debonding over time, especially in response to changing force directions.(Van Meerbeek et al., 1994)

When the lesion depth approaches 2 mm, the use of pulp-protective liners is also advised. In lesions deeper than 2 mm, there is a higher likelihood of irreversible pulpitis.

2. Disc-Shaped, Wide-Angle Lesions (90–135°) – A2

These lesions are typically associated with mild abrasion or result from acid attacks of either intrinsic or extrinsic origin, leading to erosion-induced wear. Clinically, they appear as shallow, smooth-surfaced, disc-shaped lesions. The buccolingual depth generally ranges between 1–2 mm.

For restoration, glass ionomer cements and composite resins are commonly recommended. In some cases, the shiny, sclerotic dentin present on the lesion surface should be removed using rotary instruments, and etching procedures may be employed to improve bond strength of the adhesive system by increasing surface roughness.(Loomba et al., 2014)

3. Disc-Shaped, Wide-Angle Lesions (>135°) – A3

These lesions are most often caused by erosive tooth wear resulting from repeated intrinsic and/or extrinsic acid exposure. Lesions with a buccolingual depth of less than 1 mm typically do not require restorative treatment. Instead, preventive and behavioral interventions are preferred, such as dietary modifications, use of antacids, and, when appropriate, psychological counseling to address underlying conditions such as eating disorders.

If patients report dentin hypersensitivity, desensitizing agents may be applied. In cases where the lesion depth exceeds 1 mm, restorative treatment using glass ionomer cements or composite resins may be necessary. (Loomba et al., 2014)

Current Approaches in the Prevention of Tooth Wear

In the treatment of attrition, the primary objective is the elimination or management of bruxism. Accordingly, it is recommended that a hard, transparent acrylic splint be fabricated for the patient. These splints contribute to treatment by ensuring even distribution of occlusal forces across all teeth and by correcting anterior guidance.(Macedo et al., 2007)

Before initiating restorative procedures, a comprehensive assessment should be conducted, evaluating the patient's periodontal, endodontic, occlusal, functional, and esthetic status.

Additionally, in attrition cases—where a reduction in vertical dimension is commonly observed—the presence of adequate restorative space becomes a critical factor in planning and executing successful treatment.

Clinically, abrasion lesions are observed as wedge-shaped or saucer-shaped, smooth and shiny depressions typically located on the incisal, occlusal, and cervical surfaces of teeth.(Celik et al., 2007)

In cases where the lesion has not progressed to form a deep cavity, the primary approach involves eliminating the etiological factors (e.g., improper brushing technique, use of hard-bristled toothbrushes). In more advanced cases where significant tooth structure has been lost, restorative treatment using composite resins is recommended to restore form and function.

Abfraction lesions typically appear in the cervical region of the tooth as sharp-edged, smooth, wedge-shaped defects. When the lesion width is less than 1 mm, a conservative approach involving periodic monitoring is generally recommended.(Michael et al., 2009)

For larger lesions, restorative treatment should aim to:

– Improve oral hygiene access,

– Reduce thermal sensitivity,

– Enhance esthetics, and

– Reinforce the remaining tooth structure.

The chosen restorative material and technique should address these needs while minimizing the risk of further mechanical stress at the cervical area.(Sarode & Sarode, 2013)

Dental erosion refers to a progressive process that begins with demineralization of the affected tooth surface due to continuous and prolonged exposure to acids, ultimately leading to the loss of hard dental tissue. Preventive approaches in dental erosion can be examined under three main categories: lifestyle and behavior-based strategies, self-applied methods, and professional clinical applications.

1.Lifestyle and behavior-based strategies

To determine the patient's dietary habits, a 3-day food diary should be provided in which the patient records everything consumed. This helps identify the frequency of acidic food and beverage intake.

If the assessment reveals that the patient consumes acidic items more frequently than normal, this intake should be reduced. These types of foods and drinks should preferably be consumed during main meals, when salivary flow and buffering capacity are naturally higher.

Finishing meals with calcium- and phosphate-rich foods, such as milk, cheese, or butter, can help reduce the erosive potential of acids.(Linnett & Seow, 2001)

In addition, sipping carbonated or acidic beverages slowly and holding them in the mouth can cause the salivary pH to remain below the critical level for extended periods. To reduce the risk of erosion, these beverages should be consumed quickly or through a straw, minimizing direct contact with the teeth.

Toothpastes and toothbrushes can increase the severity of erosion on already eroded tooth surfaces and may also remove the acquired pellicle, which serves as a natural protective layer. For this reason, individuals with existing erosive lesions or those at risk should be advised to use toothpastes with low to medium abrasivity and toothbrushes with soft, fine bristles.

Occupational exposure to acids also increases the risk of dental erosion. Workers in battery manufacturing and galvanization industries are particularly susceptible. For battery workers, it is recommended to reduce the duration of sulfuric acid exposure, wear protective masks, and rinse the mouth with drinking water during work hours. Scheduled rest breaks are also helpful for reducing intraoral acid presence.(Suyama et al., 2010)

NP305 protective masks, designed not to obstruct vision, are recommended for protection against sulfuric acid fumes. These masks cover the mouth and nose and contain gas filters to reduce inhalation of harmful vapors.

Dentists should refer patients with gastroesophageal reflux disease (GERD) or frequent vomiting to a gastroenterologist or psychiatrist, depending on the underlying cause. If reflux or vomiting cannot be resolved, rinsing the mouth with a sodium bicarbonate solution after episodes is beneficial. In cases where reflux occurs during sleep, occlusal splints containing sodium bicarbonate can be recommended by the dentist.(Shaw & Smith, 1999)

To stimulate saliva and promote remineralization of eroded areas, sugar-free chewing gums containing agents such as calcium phosphate may be used.(Rios et al., 2008) In patients with low salivary flow, cholinergic drugs like pilocarpine may be prescribed to stimulate salivary secretion.

To reduce the risk of erosion caused by acidic beverages, two strategies can be used:

1. Lowering the acid content of the beverage

2. Modifying the drink with ions that reduce its demineralization potential.

Additives used for this purpose include:

Monocalcium phosphate, tricalcium phosphate, calcium lactate, calcium citrate-malate complex, fluoride, and polymers such as pectin, alginate, and gum arabic.(Grenby, 1996)

Most studies focus on adding calcium and phosphate to beverages. Since 2005, soluble and deposited polymers, as well as polymer-modified beverages, have been recognized as protective agents against dental erosion.(Beyer et al., 2012)

A more recent approach involves the use of green tea extract, which is known to be rich in polyphenols. These polyphenols have been reported to function as matrix metalloproteinase (MMP) inhibitors, thereby contributing to erosion prevention.(De Moraes et al., 2016)

2. Self-Applied Preventive Methods

Neutralization of Intraoral Acidity

One of the primary self-care strategies is the neutralization of intraoral acidity. This can be achieved by utilizing the buffering capacity of the diet, incorporating neutralizing agents into chewing gums, or using antacid tablets.

Neutralizing agents that can be added to chewing gums include:

Dicalcium phosphate (mono or ortho), sodium carbonate, sodium bicarbonate, diammonium phosphate, and urea (carbamide).(Imfeld, 1996b)

Use of Toothpastes Containing Polyvalent Metal Fluorides

Toothpastes that contain polyvalent metal fluorides, such as stannous fluoride (SnF_2) and titanium tetrafluoride (TiF_4), are reported to be more effective than those with low-concentration fluoride. (Magalhães et al., 2011)Among these, SnF_2 is considered the most effective compound.

However, the concentration of stannous fluoride in toothpaste is generally lower than in solution form, and the abrasive effect of the toothpaste may slightly reduce its erosion-preventive capacity.(Huysmans et al., 2011)Therefore, it is recommended to use these toothpastes in combination with soft-bristled toothbrushes.

The protective effect of titanium tetrafluoride is explained by its ability to:

– Form an acid-resistant surface layer,

– Increase fluoride uptake, and

– Incorporate titanium ions into the hydroxyapatite crystal lattice. (Magalhães et al., 2011)

Use of High-Fluoride Toothpastes:

Enamel surfaces treated with high-concentration fluoride toothpaste show significantly greater resistance to erosive attacks compared to those treated with low-fluoride toothpaste.(Ren et al., 2011)

Use of Toothpaste/Cream Containing CPP-ACP :

Non-fluoride remineralization agents are classified into five groups:

– Casein phosphopeptide–amorphous calcium phosphate (CPP-ACP)

– Amorphous calcium phosphate (ACP)

– Calcium sodium phosphosilicate (bioactive glass)

– Tricalcium phosphate (TCP)

– Nano-hydroxyapatite

Among these, CPP-ACP acts as a calcium-phosphate reservoir on the tooth surface and helps maintain a state of supersaturation, which promotes remineralization and prevents demineralization.

Use of Toothpastes Containing Tricalcium Phosphate (TCP):

TCP ($Ca_3(PO_4)_2$) is a stable crystal structurally similar to hydroxyapatite. When combined with fluoride, it acts synergistically to enhance remineralization of the enamel surface, more effectively than fluoride alone. (Rirattanapong et al., 2017)

Use of Toothpastes Containing Novamin (Bioactive Glass):

Bioactive glass is composed of SiO_2, Na_2O, CaO, and P_2O_5.38 Although most studies focus on its role in reducing dentin hypersensitivity, bioactive glass also demonstrates remineralizing properties.(Layer, 2011; Rirattanapong et al., 2017)

Use of Toothpastes Containing Polymers:

Polymers in toothpaste are classified as organic or inorganic:

– Organic polymers include casein, ovalbumin, pectin, alginate, and gum arabic.

– Inorganic polymers include pyrophosphate, tripolyphosphate, and polyphosphate.

These polymers either form a protective surface layer or enhance the pellicle's resistance to acid erosion. Examples include mucin and carboxymethylcellulose, which strengthen the pellicle's protective function. (Schlueter et al., 2019)

Use of Toothpastes Containing Chitosan:

Chitosan, a positively charged molecule at low pH, readily binds to the negatively charged enamel. It interacts with enamel and pellicle proteins (particularly mucin) to form a protective organic layer on the tooth surface.(Magalhaes et al., 2014; Schlueter et al., 2019)

Use of Mouthrinses Containing Polyvalent Metal Fluorides:

Polyvalent metal fluoride mouthrinses are formulated as:

– Stannous fluoride (SnF_2) in combinations such as AmF/NaF/$SnCl_2$

– Titanium fluoride (TiF_4) solutions.

Use of Mouthrinses Containing Protease Inhibitors:

Collagenolytic enzymes contribute to erosive tooth wear by enhancing demineralization. Protease inhibitors such as epigallocatechin gallate (EGCG) and chlorhexidine (CHX) help to inhibit collagen degradation and reduce demineralization risk.

III. Professional Clinical Applications

Professional fluoride applications:

Fluoride gels and foams typically contain high concentrations of fluoride, up to 12.3 mg/g, and are applied by a dental professional using a custom tray.(Do & John Spencer, 2016)

One commonly recommended agent is acidulated phosphate fluoride (APF) gel, which contains 1.23% fluoride and is applied under clinical supervision.

Professional application of calcium-based preparations:

Calcium-containing agents are categorized into three main types:

– CPP-ACP (casein phosphopeptide–amorphous calcium phosphate)

– Tricalcium phosphate (TCP)

– Other advanced calcium delivery technologies.

Tooth surface protection (prophylactic coverage):

To protect the tooth surface, two categories of materials can be used:

1.Materials with remineralization potential include:

– Glass ionomer cements (GICs)

– Resin-modified glass ionomer cements (RMGICs)

2.Materials without remineralization potential include:

– Dentin bonding agents

– Pit and fissure sealants or resin sealants

Laser applications:

In recent years, the protective effect of laser treatments on enamel and dentin demineralization has gained increasing attention. Various types of lasers—such as Ruby, CO_2, Diode, Nd:YAG, and Argon lasers—have been studied under different operative modes and energy settings for their potential to enhance resistance to acid challenges.

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Chapter 5

PERIODONTAL TREATMENT IN GERIATRIC INDIVIDUALS

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Aging is defined as a series of biological, physiological, psychological, and social changes that occur throughout the lifespan, from birth to death (Dziechciaż and Filip, 2014). According to the World Health Organization (WHO), individuals aged 65 to 85 are classified as elderly, while those aged 85 and over are considered very elderly. Gerontology experts categorize aging into three distinct groups:

Young elderly (65 - 74)	*Middle-aged (75 - 84)*	*Advanced age (85 and older)*

Mitochondrial dysfunction and cellular senescence, along with the gradual slowing, reduction, and eventual loss of physiological functions over time, are commonly observed phenomena associated with general aging. The structural and functional changes that occur in tissues and organs during the aging process are similarly evident in the oral and perioral regions. A decline in regenerative capacity, alterations in cellular permeability, and a reduction in tissue elasticity negatively affect the periodontium (Gershen, 1991). Studies have reported that the rate and severity of inflammation due to poor oral hygiene are higher in elderly individuals. Additionally, the accumulation of microbial dental plaque is more pronounced in older populations. In a study by Holm-Pedersen et al., age-related changes in the host response to microbial dental plaque were reported (Holm-Pedersen et al., 1975).

Although the maintenance of masticatory function is essential for the physical and social quality of life in elderly individuals, edentulism rates remain high (Spackman and Bauer, 2012). To identify the potential causes of tooth loss, a thorough analysis of existing periodontal disease is necessary. In fact, oral and perioral health is not inherently lost as a natural consequence of aging. Rather, it is influenced by various other factors such as systemic diseases, medication use, inadequate and unbalanced dietary habits, poor oral hygiene practices, and limited access to dental care services (Turkish Dental Association – Oral and Dental Health in Advanced Age). Indicators of periodontitis in elderly individuals include microbiological (presence of periodontopathogens), behavioral (harmful habits and irregular dental visits), systemic (age, history of periodontitis), and socioeconomic factors. Effective periodontal disease management can be achieved by addressing and regulating these contributing factors (Ellen, 1992) (Figure 1).

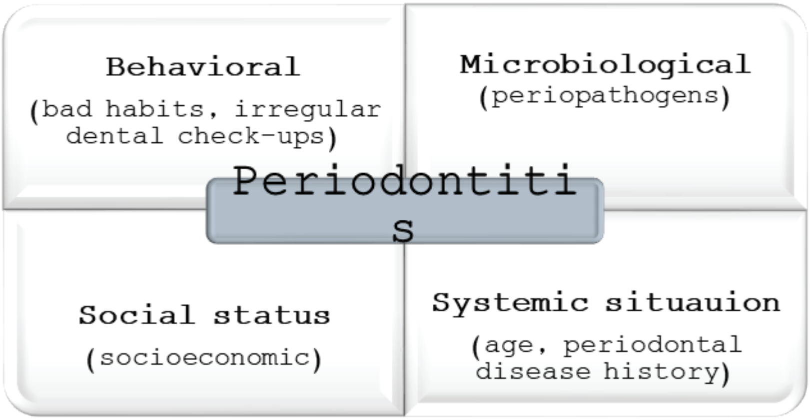

Figure 1. *Factors contributing to the development of periodontitis in geriatric individuals.*

Approach to Patients, Diagnosis, and Treatment Planning

Aggressive diagnostic and therapeutic interventions may elicit adverse reactions in geriatric individuals due to age-related general sensitivities; therefore, a gentle, sensitive, and cautious approach is essential to ensure patient cooperation. The primary goal of diagnosis and treatment in this population is to enhance quality of life and maintain acceptable functional capacity. Accordingly, when invasive or high-cost treatments are considered for elderly patients, it is crucial to evaluate the procedures from a risk-benefit perspective.

Evaluation of General Health Status

A holistic approach is essential when planning treatment. A detailed medical history should be obtained to assess the patient's current health status, including ongoing systemic conditions and regularly used medications. Additionally, mental health, neuromotor and neuromuscular function, visual and auditory capabilities, cardiovascular and respiratory system function, as well as musculoskeletal function, should be carefully evaluated (Gökçe-Kutsal, 2006). The treatment plan should be tailored to the patient in light of all this information.

Assessment of Functional Status

In addition to general health, assessing the functional status is valuable in determining the individual's self-sufficiency and the feasibility of proposed treatment interventions. For this purpose, the PULSES profile—a simple and reliable assessment scale—can be utilized (Granger, 1979) (Table 1).

***P**hysical condition*	General health condition
***U**pper limb function*	Ability to eat, drink, dress independently, use prosthetics, and maintain personal hygiene
***L**ower limb function*	Ability to go to the toilet and bathroom, climb stairs, and use a wheelchair
***S**ensory fumctions*	Hearing, ability to communicate verbally
***E**xcretory functions*	Bladder-bowel sphincter control
***S**upport factors*	Psychological, emotional, familial, social, economic

Table 1. *PULSES profile.*

This measurement provides insights into general functional performance, mobility, personal care ability, medical condition, and psychosocial factors. The classification is based on four levels of impairment: normal, mild, moderate, and severe, with six categories as mentioned above. Additionally, cognitive decline is assessed using the Mini-Mental State Examination (MMSE). The highest possible score is 30, with a threshold value between 23-24 points. Scores below 24 indicate dementia and its severity. These types of indices can be used in evaluating patients and monitoring their prognosis (Kawas and Katzman, 2001).

Behavioral Assessment

The patient's expectations regarding treatment and their persistence in this regard, as well as whether oral hygiene is maintained at a regular and sufficient level, should be assessed. If it is insufficient, it is important to determine whether the patient has realistic expectations. Additionally, the social support situation of dependent elderly individuals should be evaluated (Spackman and Bauer, 2012).

Oral Examination and Changes in Oral Tissues

A comprehensive evaluation should be performed during the oral examination.

➢ **Epithelium:** Assessment of tissue circulation, thinning, keratinized areas, and elasticity.

➢ **Tongue:** Evaluation of papillae on the dorsal side of the tongue, presence of Candida, and geographic tongue.

➢ **Saliva:** Dry mouth (xerostomia), burning sensation, changes in taste, difficulty swallowing, and speaking.

➢ **Dentition:** Evaluation of occlusion, attrition, abrasion, erosion, fractures, and presence of caries.

The treatment planning for elderly patients with complex medical problems can benefit from a systematic approach called O.S.C.A.R., which helps identify specific needs. (Table 2) (Shay, 1994)

Oral	Periodontal health - evaluation of pulp health, saliva, teeth, prosthetics, and occlusion
Systemic	Age-related physiological changes, medications used, multidisciplinary approach
Capability	Adequacy in maintaining oral hygiene and personal care, independence or dependence on others
Autonomy	Personal competence in medical information or need for assistance from another person
Reality	Economic limitations, evaluation of the expected lifespan

Table 2. *The approach used in treatment planning for patients; O.S.C.A.R.*

As a result of aging, changes in oral tissues are observed, including atrophic changes in the oral mucosa and the appearance of an edematous look. Along with dry mouth, symptoms such as burning and pain in the tongue, oral mucosa, and palate, decreased collagen levels in connective tissue and subcutaneous fat tissue, and an increase in interstitial connections can be seen (Anitha et al., 2009). Additionally, chewing power decreases due to muscle weakness, tooth substance loss is observed, and physiological changes such as thinning of the oral mucosa occur. Furthermore, the migration of the gingiva apically, exposure of the root surface leading to the formation of root caries, pathological migration and increased tooth mobility due to alveolar bone loss resulting from a history of periodontal disease, and a decrease in chewing efficiency are pathological conditions that can be observed during clinical evaluation (Lamster et al., 2016). Tooth loss due to periodontal disease is commonly seen in the elderly, and this negatively affects the quality of life (social relationships, psychological state).

In Young Individuals (%)	*Current Oral Condition / Dental Treatment Requirements*	*In Geriatric Individuals (%)*
36,7	Presence of the entire dentition in the mouth	2,1
4,2	Complete edentulism	41,1
43,6	Bleeding on probing	46,9
83,9	Calculus accumulation	88,9
51,1	≥ 1mm Gum recession	88,3
76,7	≥ 1 Attachment loss on surface	95,1
21,1	Root surface caries	56,9
79,6	Dental examination within the last 2 years	56,4

Table 3. *Comparison of oral health status and treatment needs in young and geriatric individuals.*

Periodontium

The periodontium is a structure that surrounds and supports the teeth, consisting of the gingiva, periodontal ligament, cementum, and alveolar bone. (Figure 1) In the study conducted by Kim et al., it was reported that physiological and morphological changes occur in the gingiva and periodontal ligament due to aging. (Table 4) (Kim et al. 2021).

Periodontal Ligament (PDL)	*Gingiva*
(--)Cell & fiber density	(--)Cell proliferation & migration capacity
(--)Alkaline phosphatase activity	(--)Pro-apoptotic gene transfer
(--)Organic matrix production	(--)Collagen remodeling
(--)Type 1 & Type 3 collagen	(--)Repair capacity
(--)Mineral nodule formation	(+)Anti-apoptotic gene transfer
(--)Cellular mitotic activity	(+)Width of attached gingiva
(--)Wound healing & regenerative capacity	
(--)Expansion in the PDL space	
(+)Aged cell population	
(+)Pro-inflammatory gene	

Table 4. *Age-related changes observed in the periodontal ligament (PDL) and gingiva. (+): increase, (--): decrease.*

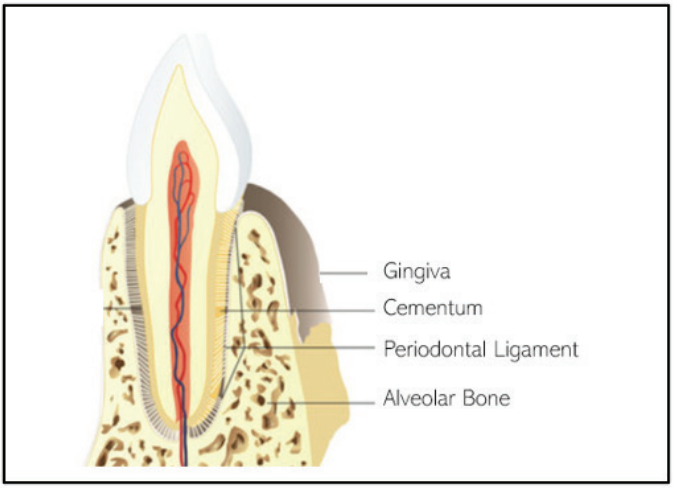

Figure 2. *Periodontium (Cafiero C, Matarasso S. Predictive, preventive, personalised and participatory periodontology: 'the 5Ps age' has already started. EPMA J. 2013 Jun 14;4(1):16)*

Thinning of the gingival epithelial layer, reduction in keratinization, increased epithelial permeability, and a decrease in the host's response to environmental stimuli are changes observed in the periodontium over the long term. (Newman et al. 2019) Furthermore, with aging, the stippling appearance decreases, cell numbers change, and there is an increase in the thickness and density of connective tissue, while the number of cells decreases. (Ryan et al. 1974) In the study by Dumas et al., it was reported that there are morphological and functional differences in fibroblasts, despite the excess collagen in the connective tissue. (Dumas et al. 1994) Periodontal surgeries are not contraindicated in geriatric individuals. However, systemic diseases and complications related to regularly used medications must be considered as they can affect the periodontal treatment plan. Controlling plaque will help maintain periodontal health in the long term. (Al-Ghutaimel et al. 2014).

Periodontal Ligament (PDL)

After tooth loss, it has been reported that the width of the periodontal ligament increases with the functional load, or decreases due to reduced masticatory force and insufficient function (Niver et al. 2011). With advancing age, fibroblasts are seen in smaller numbers and in an irregular structure in the periodontal ligament compared to changes in the connective tissue. Additionally, the amount of elastic fibers increases, and the production of the organic matrix decreases (Abiko et al. 1998). With aging, the reduction in the force transmitted to the periodontium from the masticatory muscles in a hypofunctional state results in a decrease in periodontal ligament width. On the other hand, tooth loss leads to an increase in the chewing forces transmitted to the remaining teeth, which results in an increase in the width of the periodontal ligament (Huttner et al. 2009).

Alveolar Bone

With aging, osteoporotic changes can occur, cortical bone may undergo resorption, and bone marrow may expand. Women are more affected than men due to estrogen hormone. The integrity of the alveolar bone is influenced by the preservation or loss of the existing teeth (Palmqvist and Sjödin 1987). If functional forces are not transmitted to the bone due to tooth loss, the balance between bone formation and resorption shifts in favor of resorption (Pockpa et al. 2019). Additionally, it has been stated that blood flow decreases in both jaws with aging, which may be due to tooth loss and changes in the vascular structures (Hiltunen et al. 2003).

Saliva

Dry mouth is a common condition in elderly individuals. Insufficient daily water intake, diabetes, Sjögren's syndrome, and salivary gland diseases can result in dry mouth. Similar conditions can also be seen in individuals undergoing radiotherapy and chemotherapy. Along with dry mouth, there is a reduction in the lubrication of the oral mucosa, decreased resistance to mechanical trauma, and an increased tendency to gingival inflammation. This condition also increases susceptibility to oral ulcerative lesions (Guggenheimer and Moore 2003). Changes in taste, burning sensation, and difficulties in swallowing and speaking can also occur (Turner and Ship 2007).

Epithelium and Connective Tissue

In elderly individuals, thinning of the gingival epithelium, reduction in keratinization, increased epithelial permeability, and decreased resistance to trauma are long-term changes observed in the periodontium. The rete pegs in the gingival epithelium become more flattened, stippling appearance diminishes, and cellular density changes. There is an increase in intercellular substance in supporting tissues, as well as changes in cell density and mitotic activity. (Feres et al. 2016) Additionally, with increasing age, the gingival connective tissue thickness and density increase, while the number of cells decreases. (Ryan et al. 1974) Studies have shown that with age, morphological and functional changes occur in fibroblasts, and despite a decrease in collagen synthesis, high levels of collagen are observed in the connective tissue. (Newman et al. 2019) The maturation rate of the collagen produced also increases. (Gogly et al. 1997) The elasticity of the connective tissue in the oral mucosa and fibrosis increase with age. Furthermore, gingival vascularization is negatively affected. With aging, there is a decrease in the metabolic capacity of the gingiva. (Curtis et al. 2021)

Dental Implant Applications in Geriatric Individuals

With advancing age, the increase in tooth loss results in a greater need for prostheses in elderly individuals compared to younger individuals. (Arpak, Paksoy, and Ereş 1990) Removable partial and complete dentures are often preferred, but these prostheses lead to a reduction in masticatory force and may result in some adverse conditions such as angular cheilitis, candidal infections, and denture stomatitis. (Özdemir, Turgut, and Polat 2003) Satisfaction with prostheses is generally low in geriatric individuals, and problems related to prosthesis use cannot be prevented due to insufficient oral hygiene practices. (Özdemir, Turgut, and Polat 2003, Akşit et al. 2012) In patients using removable partial and complete dentures, alveolar bone loss is observed, and with increased lifespan, this bone loss is expected to increase further with prolonged use of these prostheses, making the use of dentures more challenging. The expectation for maintaining the quality of life in geriatric individuals is to create a dentition that ensures both function and aesthetics. In individuals seeking dental care due to tooth loss, implant and prosthetic options, including both removable and fixed dentures, can be applied based on the individual's medical, dental, and socioeconomic status. (Haştar, Yılmaz, and Orhan 2010, Stanford 2007)

There are specific considerations when performing implant surgery on elderly individuals. While aging is not a contraindication for implant procedures, the changing physiology, healing capacity of tissues, systemic diseases, and medications must not be ignored, and a detailed medical history should be obtained. With advancing age, when evaluating the periodontium, epithelial thinning, reduced keratinization, decreased collagen synthesis in periodontal ligament cells, a decrease in osteogenic stem cells, and a reduction in local and systemic blood flow are observed. (Huttner et al. 2009, Severson et al. 1978, Tonna 1976, Strube et al. 2008)

The healing process is naturally delayed in elderly individuals, with slower cellular proliferation, collagen synthesis, and wound metabolism. As long as there is no systemic condition that impairs the healing process, surgical results are not negatively affected and can be safely performed. (Goodson 1979, Minimas 2007, Zarb and Schmitt 1994) Studies have shown that the success of osseointegration in implant surgeries is similar in both young and elderly individuals. (Kondel et al. 1988) A retrospective study found that the success rates and survival of implants in elderly individuals were not different from those in younger individuals. (Bryant and Zarb 2002, Engfors et al. 2004, Grant and Kraut 2007)

Risk Factors for Dental Implant Success in Geriatric Individuals

The biggest risk in these individuals is medical complications that can affect wound healing and bone density. (Goodson 1979, Minimas 2007) Diabetes and osteoporosis are important metabolic conditions due to their prevalence in elderly individuals and their effects on bone metabolism. Additionally, long-term smoking and postmenopausal estrogen therapy are factors that influence implant success and are areas of ongoing research. (Moy et al. 2005) Steroids and bisphosphonates, which affect bone metabolism, can impact the success of dental implant surgeries. (Hwang and Wang 2007)

Osteoporosis

Osteoporosis is the most common bone disease that leads to a decrease in bone quantity and quality, making bones more fragile and prone to fractures. As life expectancy increases, the incidence of osteoporosis and related fractures is rising worldwide. Studies have reported that 1 in 5 men and 1 in 3 women over the age of 50 have osteoporosis. (Turkish Osteoporosis Association) The most commonly used classification for osteoporosis is based on etiological factors. (Table 5)

Primary Osteoporosis	It occurs as a result of menopause or aging
Secondary Osteoporosis	It is a condition where the cause is related to another disease or medication use, malnutrition, and insufficient physical activity. (Gökçe 2008)

Table 5. *Classification of osteoporosis according to etiological factors.*

Although osteoporosis is defined as a systemic skeletal disease, it can also be localized in some cases. When implant surgery is planned for these patients, diagnosis and treatment are crucial. Osteoporosis is commonly seen in postmenopausal women, and randomized controlled studies have highlighted failed implant procedures in these individuals. (Becker et al.

2000) Some studies suggest that bone quality deterioration may prevent osseointegration, leading to the contraindication of dental implants in patients with osteoporosis. (Gaetti-Jardim et al. 2011) In contrast, other studies indicate that this condition does not create a contraindication, and osseointegration can still be achieved, even in cases of severe osteoporosis, with results similar to those in healthy individuals. (Bryant and Zarb 2002, Dao et al. 1993, Friberg 1994) Preoperative three-dimensional imaging of the relevant region allows for bone quality evaluation, and the application of wide-diameter implants can improve osseointegration. (Gaetti-Jardim et al. 2011)

In conclusion, implant treatments can be applied to individuals with osteoporosis, and long-term success can be achieved. However, careful evaluation of factors that may increase risk in osteoporotic patients, as well as multidisciplinary approaches, is essential. Particularly, the use of corticosteroids and uncontrolled diabetes in secondary osteoporosis can decrease the success of the procedure.

Diabetes

Delayed immune response to infections, delayed wound healing, susceptibility to periodontal disease, microvascular diseases, retinopathy, and neuropathy are common complications of diabetes. Microvascular damage can lead to failure of implant treatments. Additionally, changes in mineral and bone metabolism can negatively affect osseointegration. (Wood and Vermilyea 2004) In elderly individuals with well-controlled long-term diabetes, the survival rate of implants is reported to be 85%, with successful outcomes. (Fiorellini and Nevins 2000, Kapur et al. 1998) Although studies show that success rates for diabetic patients are slightly lower compared to healthy individuals, this difference is not significant enough to be a major concern. (Morris, Ochi, and Winkler 2000)

Important Considerations

When performing implant procedures in geriatric individuals, the following factors must be considered:

- Awareness of the physiological, pathological, and psychological effects of aging.

- Systemic diseases and regular medications should be considered as they can affect osseointegration.

- Smoking, uncontrolled diabetes, and cardiovascular diseases create partial contraindications.

- Bisphosphonates and steroid use may affect the outcome of implant therapy.

- Implants should not be recommended to patients who have been edentulous for a long time and are satisfied with their current dentures.

Conclusion

The physiological changes associated with aging also manifest in the periodontal tissues. To minimize the damage to the periodontium and subsequent tooth loss, regular dental check-ups and treatments must be emphasized. Periodontal and dental issues in geriatric individuals should be promptly addressed, and if conditions like dry mouth are present, appropriate interventions should be made after providing necessary information. Implant treatments, apart from certain absolute contraindications, can be performed at any age and this should be communicated to the patients. Treatment planning in the presence of systemic diseases and regular medication use should be done with a multidisciplinary approach. To maintain chewing function, aesthetics, and phonation as individuals age, it is advised that they maintain regular communication with their dentists.

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