Integrated Approaches in Contemporary Dentistry

Multidisciplinary Perspectives Centered on Orthodontics

Asst. Prof. Dr. Gizem Yazdan OZEN

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Chapter 1

What is Orthodontics?

Gizem Yazdan Özen[1]

Abstract

Orthodontics is a specialized branch of dentistry that examines the harmony of the teeth, jaw, and facial system. It involves the diagnosis, prevention, and treatment of issues such as misaligned teeth, jaw discrepancies, and malocclusion (bite disorders). Orthodontic treatment not only provides an aesthetically pleasing smile but also helps improve functions such as chewing, speaking, and breathing.

Depending on the time of the patient's application, preventive, interceptive, and/or corrective procedures can be implemented in orthodontic treatments. Preventive orthodontic treatments include fissure-sealant applications, space maintainers, and the preservation of primary tooth contacts. Interceptive orthodontic treatments involve techniques such as serial extractions and eruption guidance appliances (EAG).

Orthodontic treatments are not limited to brackets applied to teeth but also include various intra-oral and extra-oral appliances that create orthopedic effects, as well as orthognathic treatments for adult patients.

Oral and dental health is among the most common health issues worldwide, with individuals encountering these problems at least once in their lifetime. Along with dental caries, gum diseases, and fluorosis, malocclusions are among the most prevalent problems (Zakirulla et al., 2019).

In society, malocclusion (bite disorders) is often perceived as purely dental issues. However, malocclusion also involves skeletal discrepancies between the jaws (Siddegowda & Rani, 2013). Individuals with malocclusion may experience speech disorders, aesthetic concerns, and issues within the chewing system (Babu et al., 2005). Addressing these problems through orthodontic treatment is crucial for individuals to lead healthier lives (Muqtadir Quadri et al., 2015; Zakirulla et al., 2019).

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Orthodontics aims to diagnose and treat disorders in the teeth, jaw, and facial system and prevent malocclusions (Erhamza & Ciğerim, 2021). Orthodontists intervene at different developmental stages of individuals to prevent these disorders. In preventive orthodontics, treatment is conducted without using any orthodontic mechanics. Interceptive orthodontic treatments aim to prevent problems through simple guidance, while active orthodontic interventions are applied based on the severity of the anomaly and the individual's developmental stage.

1.Preventive Orthodontics

The primary and fundamental goal of orthodontic treatment is to prevent the development of orthodontic problems (malocclusions/anomalies) in children. Preventive orthodontics aims to carry out treatments without the use of orthodontic mechanics (Meriç, 2018).

Preventive orthodontic treatments include: fissure-sealant applications, fixed or removable space maintainers, preservation of mesiodistal dimensions and primary tooth contacts.

The risk of cavities in the pits and fissures of primary and permanent posterior teeth is quite high. Resin-based materials applied to these surfaces to protect them are called fissure sealants (Meriç, 2018). These materials act as a physical barrier against acids produced by bacterial plaque (Ferracane, 2001). The application of fissure sealants, combined with good brushing habits, can prevent early childhood cavities and, consequently, premature tooth loss.

Early loss of primary teeth can lead to space loss in the dental arch, which may result in crowding. Space maintainers are used to prevent space loss in the dental arch due to early tooth loss. These maintainers can be fixed or removable, with several variations available. When designing space maintainers, factors such as root development, alveolar ridge, and the distance between permanent teeth should be considered (Kanellis, 2001). Incorrect applications intended to help individuals may, in fact, cause harm.

In the mixed and primary dentition periods, deviations from the ideal mandibular occlusion can occur due to primary contacts. This adaptation makes the correction of malocclusion more difficult. In cases involving the primary canines, minor modifications such as selective grinding can be applied as preventive orthodontic measures (Ülgen, 1993). Incorrect fillings on primary teeth during early stages may disrupt primary contacts, leading to space loss in the dental arch.

2.Interceptive Orthodontics

If an anomaly and/or malocclusion cannot be prevented in its early stages, interceptive orthodontic treatments are applied to prevent further severity (Ülgen, 2001).

Interceptive orthodontic treatments include: serial extractions, eruption guidance, prevention of harmful habits, and habit-breaking appliances.

Thumb-sucking in infancy and early childhood can be considered normal outside of feeding (Johnson & Larson, 1993). However, persistent habits such as thumb-sucking, lip-sucking, tongue-sucking, and swallowing disorders can lead to malocclusions and/or various anomalies. The severity and duration of these habits determine the extent of the resulting anomalies. If these habits are identified early and disappear naturally, problems may resolve without the need for treatment. However, if intervention is necessary, the recommended period is between 4 years of age and the eruption of permanent incisors (Johnson & Larson, 1993; Nanda, 1972). While it is a fact that bad habits can be solved with early intervention, if intervention is not made on time, various negativities may occur depending on the type and severity of the anomaly. For example, as a result of finger sucking habit, prolonged use of pacifiers, deepening in the maxillary palatinal region, vestibular angulation in the upper incisors, lingual angulation in the lower incisors and narrowing of the respiratory tract can be seen. With the habit of nail biting, intrusions and abrasions on the incisal/occlusal edges can be seen in teeth and/or tooth groups where the habit is practiced continuously. In the case of lip sucking, the mucous membrane of the lips on the sucking side is redder and more swollen than the other half.

The concept of eruption guidance was introduced into the literature by Hotz. While the technique of serial extraction was already known, Hotz provided a new perspective on the topic. Hotz categorized space stenosis into three groups: true space stenosis, symptomatic space stenosis and the combination of these two. In true space stenosis, he talks about the incompatibility between the mesio-distal dimension of the teeth and the jaw bone, while in symptomatic space stenosis, he talks about the loss of arch length and the resulting space stenosis that occurs as a result of interdental caries in deciduous teeth or early deciduous tooth extraction. In the third group, a combination of these two is mentioned (Hotz, 1970). The main purpose of eruption guidance is to solve dental problems with early intervention in individuals who are likely to develop crowding in the future. Erosion guidance is examined in three groups: eruption guidance without considering permanent tooth extraction, eruption guidance with space constraints, eruption guidance with space constraints and permanent tooth extraction (orthodontic serial extraction), and eruption guidance performed in congenital tooth deficiency (Ülgen, 2001).

One step beyond sliding guidance is serial extraction treatments. Serial extractions were first introduced by Bunon (Bunon, 1746) and developed by Kjellgren (Kjellgren, 2007). Serial extraction is a treatment method that includes extraction of deciduous and permanent teeth without orthodontic appliances when the molar relationship is class I and the space stenosis is 7 mm or more. (Yoshihara et al., 2000)

3.Corrective Orthodontics

In our region, orthodontic problems often go unnoticed until they become visibly severe, leading individuals and parents to neglect the need for treatment. However, if these problems are addressed at an early age, they can be effectively treated.

The goals of orthodontic treatment include (Ülgen, 2001):

- Improving chewing, speech, and breathing functions
- Enhancing the teeth, jaw, and facial system
- Ensuring the long-term stability of treatment results
- Positively affecting the patient's psychological well-being

Corrective orthodontic treatments can be categorized into dental corrections, orthopedic treatments planned during pubertal growth and development, and orthognathic treatments for adult patients with severe skeletal anomalies.

Today, orthodontic treatments can be performed not only with metal bracket systems but also with clear aligners. While treatment mechanics and planning remain similar, the materials used differ. The most important rule in orthopedic treatments is that patients should not have completed their pubertal growth spurt.

A separate and significant area in orthodontics involves treating individuals with cleft lip and palate (CLP) and syndromic conditions. CLP patients require long-term follow-up from birth, with treatment starting with feeding plates.

4.The Beginning of Orthodontics in Dentistry

Dentistry and orthodontics have been included in general medicine for many years. It is known that the first book on dentistry was the book titled 'Arznei Buchlein' (1530), the author of which is unknown, and that this book was published in Leipzig and was printed and used many times until 1576. In this book, some orthodontic anomalies were described (Perkün, 1973).

In 1860, Angell published the first article on maxillary expansion in 'Dental Cosmos' (Angell, 1860).

In 1872, Kingsley introduced the use of headgear to apply posterior force to the maxilla in the orthodontic literature (Ülgen, 2001).

Edward H. Angell is the most famous person in orthodontics (Ülgen, 2001). The classification he created with his own name is still actively used today.

It was Tweed, also one of Angell's students, who came after Angell and recommended and practiced gravitational treatment as an alternative to Angell's non-gravitational treatment method (Tweed).

Begg, also one of Angell's students, introduced the Begg technique, which requires extraction in all treatments, to the literature (Begg, 1961).

The first orthodontic applications were initiated by Pierre Fauchard in 1728 (Fauchard, 1746).

Cellier applied extraoral force to the mandible with the chin-cup in 1802 (Wahl, 2005).

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Chapter 2

Orthodontics and Oral, Dental, and Maxillofacial Radiology: Multidisciplinary Treatments and Contemporary Approaches

Gizem Yazdan Özen[1]

Abstract

The discovery of X-rays by Wilhelm Roentgen was a groundbreaking development in medical history. This revolutionary discovery was quickly adopted in dentistry, making radiographic imaging an indispensable tool for diagnosis and treatment processes. Initially, radiology education was provided by medical professionals, but over time, it was integrated into the field of dentistry.

Radiographic imaging, which began with manual methods, has largely transitioned to digital systems today. Particularly in oral, dental, and maxillofacial radiology and orthodontics, these two fundamental disciplines complement each other in diagnosing and treating complex cases. In orthodontic treatment planning, radiological imaging provides a detailed assessment of bone structures, tooth positions, and jaw relationships, guiding the treatment process.

Advanced imaging techniques such as digital radiography, cone-beam computed tomography (CBCT), and magnetic resonance imaging (MRI) have become prominent. These technologies enable more precise diagnoses and allow for the development of highly personalized treatment plans. The integration of orthodontics and oral, dental, and maxillofacial radiology has significantly advanced diagnostic and treatment processes in modern dentistry.

The discovery of X-rays by Wilhelm Conrad Roentgen in 1895 marked a revolution in medical history. Roentgen captured an image of his wife's hand using a 15-minute exposure and was awarded the Nobel Prize in

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Physics in 1901 for his groundbreaking discovery (Fields Jr & Goaz, 1995; Ozden & Ünver, 1946).

Shortly after Roentgen's discovery, this new invention gained attention worldwide, including in Türkiye. Articles were published in daily newspapers to inform the public about X-rays. The first individuals to work with X-rays were photographers and physicists (Fields Jr & Goaz, 1995). In Türkiye, the first use of X-rays in medicine occurred in 1896 when Captain Dr. Esat Feyzi Bey and Captain Dr. Rifat Osman Bey at the Military Medical School captured an image of a student's hand. In 1897, during the Ottoman-Greek War, these doctors used Crooks tubes to locate bone fractures and bullets in wounded soldiers (Ozden & Ünver, 1946; Pırnar & Dicle, 1995).

However, the introduction of X-rays into dentistry in Türkiye was not as rapid as in medicine. In 1924, dentists Hasan Hayri Bey and Sezai Zühtü Bey submitted a report to the Ministry of Health, which led to the acquisition of an X-ray device for a dental school. Despite acquiring the device, the first radiology department was established in a separate building in the dental school's garden under the directive of Professor Server Hilmi Bey. The department was led by Hüseyin Talat Bey and later separated from the school following the university reform of 1933 (Canger & Çelenk, 2012).

Radiology courses were incorporated into the dentistry curriculum in 1927. Dr. Mehmet Selahattin Erk was assigned to teach radiology to both medical and dental students (Erden, 1948; Gürkan, 1951).

With technological advancements, imaging methods in dentistry have evolved from printed images to digital systems, making them essential tools in diagnosis and treatment planning. Digital imaging offers advantages such as high-resolution images, real-time assessment, and efficient storage of patient records. Additionally, innovations such as reduced radiation exposure, three-dimensional imaging techniques, and artificial intelligence-supported analysis continue to enhance the field.

Digital radiography converts X-ray images into electrical signals. The goal of digital radiography is to detect dental diseases and provide treatment insights, much like film-based techniques that offer information about dental structures and surrounding tissues. Two main methods are used in digital imaging: direct and indirect techniques (Yeler et al., 2006).

Direct digital imaging is divided into two systems according to whether the image is formed directly on the screen after irradiation or whether there is an intermediate phase. The system with an intermediate phase is also called quasi-direct (Hintze et al., 1994).

Radiovisiography (RVG) (Trophy Radiology, France) was the first imaging technique in a direct digital radiography system and was introduced by Dr. Frances Mouyens in 1984. Since then, different imaging systems have been introduced to the market with different resolution values, matrix sizes, sensor types and pixel values while keeping the working principle the same (Parks & Williamson, 2002).

The indirect digital imaging system includes CCD cameras and computers. The working principle is that radiography provides scanning with a CCD camera and directs it to the computer screen, where it is displayed on the computer screen (Yeler et al., 2006).

1.Radiological Imaging Tools Used in Dentistry and Orthodontics

Accurate diagnosis and effective treatment planning in dentistry rely heavily on imaging techniques. The evolution from traditional radiographic techniques to digital systems has brought significant advancements, allowing for the evaluation of not only teeth and surrounding tissues but also bone structures, sinuses, joints, and soft tissues. Key developments such as reduced radiation doses, high-resolution imaging, and widespread use of three-dimensional imaging have improved diagnostic accuracy.

Today, the following imaging methods are commonly used in dentistry for diagnostic and therapeutic purposes:

- Panoramic Radiography
- Digital Periapical Radiographs
- Occlusal Radiographs
- Lateral Cephalometric Radiography
- Antero-posterior Cephalometric Radiography
- Postero-anterior Cephalometric Radiography
- Hand-Wrist Radiographs
- Cone-Beam Computed Tomography (CBCT)
- Ultrasound Imaging
- Magnetic Resonance Imaging (MRI)

1.1. Lateral Cephalometric Radiographs

Lateral cephalometric films, which are essential for a comprehensive and detailed orthodontic treatment planning, should be taken only when necessary, like all radiographic records. The relationship and analysis of all structures in the cranial region from the films taken helps to determine the diagnosis and treatment method.(Proffit & Fields, 2013) (Figure 1)

In their 1992 study, Atchison et al. reported that orthodontic treatments can change the treatment planning by approximately 20% with the analysis of lateral cephalometric films. (Atchison et al., 1992) Today, this rate is still acceptable. Most of the anomalies present in individuals may be masked by the surrounding soft and/or hard tissues and this may lead to misleading treatment plans.

In cases where lateral cephalometric films are used as follow-up films, they are also known to be helpful treatment tools in determining the direction and speed of growth and/or the course of treatment.

Figure 1. Lateral Cephalometric film

1.2.Cephalometric Analysis

The main purpose of cephalometric films is to guide the orthodontist in diagnosis and treatment by determining the conditions that occur as a result of dental, skeletal and/or combination of these problems in patients.(Figure 2)

Figure 2. A manually prepared cephalometric drawing

Cephalometric analysis was first popularized by Down's after World War II. Although it was initially difficult to establish norms for reference values, this was overcome by calculating reference values for individuals with perfect facial proportions and occlusion (Proffit & Fields, 2013).

Analyses such as Down's (Downs, 1956), Steiner (Steiner, 1953), Wits (Jacobson, 1976), Jarabak, Sassouni (Sassouni, 1958) are still relevant and actively used today.

The Steiner analysis was the first orthodontic analysis developed by Cecil Steiner in the 1950s. In the analysis, he prepared not only individual measurements but also a treatment plan that guides the comparison of these measurements. In his analysis, he mentioned the orthodontically important SNA, SNB and ANB, which indicates the relationship between the jaws. He also utilized angular and linear measurements of the upper incisor NA and lower incisor NB to evaluate the protrusion of the incisors. (Steiner, 1953)

Down's analysis (Downs, 1956) is a measurement consisting of five skeletal and five dental measurements without soft tissue measurement and treatment plan. The skeletal measurements examine the position of the maxilla and mandible relative to each other and to the cranium, while the dental measurements examine the relationship of the teeth to each other and to the jaw bones.

Tweed analysis begins with three planes that form the triangle known as the Tweed triangle. These planes are the Frankfort horizontal plane, the mandibular plane, and the plane formed by the long axis of the lower incisor (Jain et al., 2017). The Frankfort plane is drawn using the midpoint of the skeletal orbital points on both sides as a reference, along with a point 4.5 mm above the geometric center of the ear rod. The mandibular plane is drawn tangentially along the lower border of the mandible. The third plane is drawn using the long axis of the lower incisor as a reference. By combining these three planes, the Tweed triangle is formed. The three angles located at the three vertices of this triangle serve as references for the evaluation in this analysis. These angles are called FMA, FMIA, and IMPA.

1.3.Postero-Anterior Radiographs

Unlike lateral radiographs, frontal radiographs are used to determine maxilla, mandible and various facial asymmetries and to evaluate vertical directional measurements in the craniofacial region and oral structures (Jacobson, 1995). When used in conjunction with lateral cephalometric evaluations, they can be informative for the craniofacial and dentofacial complex in all 3 dimensions (Athanasiou, 1995)

Although postero-anterior radiographs are one of the leading 2D imaging methods used by orthodontists in facial asymmetries, they are not preferred by clinicians (Figure 3). In the literature, this radiography group has been used in the evaluation of syndromes and craniofacial asymmetry (Grummons et al., 1987; Svanholt & Solow, 1977).

Figure 3. Postero-anterior cephalometric radiography

1.4.Panoramic Radiographs

Panoramic (orthopantomography) radiographs are the most commonly used radiographs in dentistry to visualize the maxilla and mandible and dental structures on a single film (Koç & Özbek, 2021) (Figure 4). Nowadays, it is known that almost every dental clinic has at least one radiography device.

In Panoramic radiographs;

- Teeth,
- Maxilla
- Maxillary sinus
- Mandibular
- Nasal septum,
- Nasal cavity,
- Zygomatic arc,
- Orbital base,
- Articular eminence,
- Styloid processes,

- Cervical vertebrae,

- Hyoid bone,

- Nasal soft tissue,

- Soft palate,

- Uvula,

- Tongue,

- Nasopharyngeal,

- Glossopharyngeal and palatoglossal airways can be monitored.

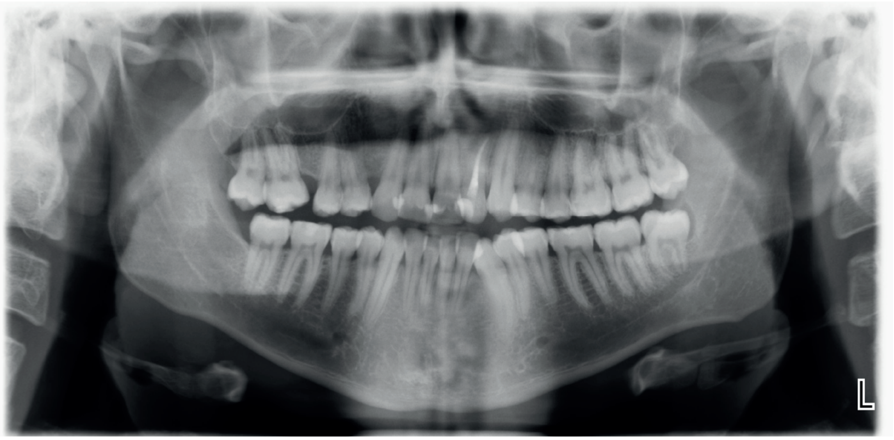

Figure 4. Panoramic Radiography

1.5.Digital Periapical Radiographs

Periapical radiographs perform imaging in a more specific area than other radiographs. They provide a detailed representation of the relationships of the teeth with the crown, root and surrounding tissues (Özcan, 2017).

The aim of use in orthodontics is;

- Evaluation of the development, eruption time and position of teeth
- Dimensions of the teeth, assessment of the presence of shape anomalies
- Evaluation of root resorption of deciduous teeth in deciduous and/or mixed dentition
- Evaluation of root formation stages of permanent teeth

- Evaluation of the inclination of the tooth roots.

1.6.Occlusal Radiographs

It is a film group that helps to see the teeth and jaw bases in the upper and lower jaw in a single film. It can be used to monitor erupting teeth, fractures in the maxilla or mandible, determine the position of plus teeth, evaluate soft and/or hard tissue problems, and control the separation of the suture palatine media to control the skeletal change of the maxillary expansion appliance. (Scheller-Sheridan, 2013) (Figure 5).

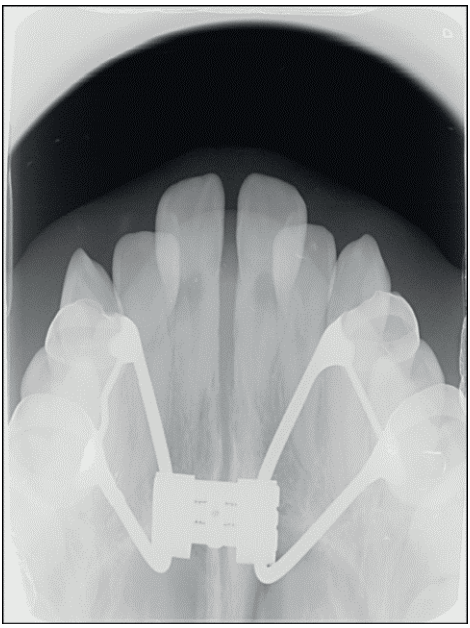

Figure 5. Example of occlusal radiograph

1.7.Cone Beam Computed Tomography (CBCT)

Towards the end of the 1960s, computed tomography was first used in the UK (Hounsfield, 1973). The first clinical application was performed by Dr. James Ambrose (Ambrose, 1973).The examination of craniofacial structures was first performed by Mozzo and colleagues (Mozzo et al., 1998).

The scanning process can be performed standing, sitting and/or lying down (Caloss et al., 2007; Scarfe & Farman, 2008), the artifact has a less clear image (Scarfe & Farman, 2008), the scanning time is short (Scarfe &

Farman, 2008; Scarfe et al, 2010), the data obtained are in DICOM (Digital Imaging and Communications in Medicine) format (Kau et al., 2009) and can be transferred to an external memory (White & Pharoah, 2008) are among the advantages of cone beam computed tomography.

It is known that the images obtained with CBCT are identical to the original images (Lagravère et al., 2008). This provides more precise and reliable results. It can also be used to determine the status of the anomaly and the depth of the defect in individuals with cleft lip and palate (Baba et al., 2002) and to evaluate the effect of rapid upper jaw expansion on the respiratory tract (Garrett et al., 2008; Lagravère et al., 2010; Lagravère et al., 2008). CBCT is also used in the construction and evaluation of dental implants.

CBCT is currently used for various purposes in all branches of dentistry and is gradually replacing other radiographic imaging techniques.

1.8.Hand-Wrist Radiographs

Wrist radiographs were recorded shortly after the discovery of X-rays and started to be used in the assessment of skeletal development. The main reason for their use in the evaluation of skeletal development is that as many bones with ossification periods as possible can be visualized together in a single film and these films can be obtained more easily than other parts of the body.(Figure 6)

Figure 6. Example of a wrist radiograph

1.9. Ultrasonography

It can be defined as mechanical energy consisting of acoustic waves at frequencies higher than the hearing level of the human ear. In medicine for diagnostic purposes, it is generally preferred in cases such as pregnancy where radiation applications are harmful (Atıcı & Ertaş, 2014).

Ultrasound can be used in various fields in dentistry. The main ones are evaluation of orthodontic root resorption (El-Bialy et al., 2004), treatment of temporomandibular joint disorders (Erickson, 1964), periodontal healing (Ikai et al., 2008).

Insufficient mandibular growth can lead to impaired dental occlusion and deformations in facial aesthetics (Proffit et al., 2006). In cases of advanced mandibular insufficiency, the main treatment options are orthognathic surgery or distraction osteogenesis (Molina, 2009), and functional appliances may be preferred to prevent complications related to surgery (Moulin-Romsée et al., 2004). There is a need for alternative methods that can provide faster and more effective results in the treatment of mandibular insufficiency. In this context, studies evaluating the effectiveness of low-intensity intermittent ultrasound are limited (Khan et al., 2013). El-Bialy et al. examined the effectiveness of low-intensity intermittent ultrasound on mandibular growth and reported that the growth was higher in the applied group (El-Bialy et al., 2006). Oyonarte et al. reported that low-intensity intermittent ultrasound affects mandibular growth at the bone and cartilage level (Oyonarte et al., 2013).

1.10. Magnetic Resonance Imaging (MRI)

It works in a completely different structure than other imaging systems. It works on the principle that water molecules in tissues move as a result of radio waves (Brooks & Miles, 1993; Edwards, 1993).

Since it is a noninvasive technique, it is widely used in dentistry. However, although it is a sensitive technique, its specificity is not as high.

MRI has many advantages:

- It does not emit ionizing radiation
- It can be used for soft tissue examination
- It allows cross-sectional examination of images (Kondoh et al., 1998; Nebbe et al., 1998)

Although it is mostly used in temporamandibular joint imaging in dentistry, it can also be used in cases of cleft lip and palate, cysts and malignant lesions in the maxillofacial region (Edwards, 1993).

1.11.Stereophotogrammeters

The basis of stereophotogrammetry is the steroscopic vision principle that exists in all living things in nature. According to this principle, the third dimensions of the objects existing in nature are overcome by visual perception from different angles and objects are perceived in 3D. Stereophotogrammetry is based on obtaining a 3D image by combining images taken with at least 2 imaging devices at equal distances from the object (Görgülü et al., 2015; Ras et al., 1995; Tzou & Frey, 2011)

In today's technology, it is ideally used in the examination of soft tissues (Görgülü et al., 2015; Kau et al., 2010).

In the field of orthodontics, it is used;

- When analyzing soft tissue differences by age race sex (Tanikawa et al., 2016)
- In smile aesthetic evaluations (van der Meer et al., 2014)
- In 3D soft tissue image archives of individuals (Rosati et al., 2010; van der Meer et al., 2014)
- In asymmetry assessments (Edler et al., 2003)
- In omage comparisons before and after treatment,(Rosati et al., 2010)
- In Growth and development studies (Wong et al., 2008)
- In the assessment of various syndromes (Fourie et al., 2011).

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Chapter 3

Multidisciplinary Treatments And Current Approaches In The Orthodontic-Restorative Interface

Büşra Tekin[1]

Abstract

The collaboration between orthodontic and restorative dental treatment is crucial to ensure their ideal results. This partnership aims to integrate orthodontic alignment with restorative procedures to achieve functional and aesthetic dental results. This collaboration is especially important when addressing complex dental cases involving misalignment, crowding, or spacing that require both orthodontic correction and restorative solutions. By properly aligning the teeth before or after the restorative procedure, orthodontists create an ideal foundation for the restorative workflow, removing as little material as possible from healthy dental tissues, ensuring the long-term success and durability of treatments. This multidisciplinary approach not only improves patient satisfaction, but also prevents complications, resulting in better oral health and stability. In conclusion, orthodontic-restorative collaboration plays an important role in modern comprehensive dental care.

Introduction and Conceptual Framework for Interdisciplinary Orthodontic and Restorative Treatment

In contemporary dentistry, the integration of orthodontic and restorative treatment modalities has emerged as a cornerstone for achieving optimal outcomes in both function and aesthetics. As early as the late 20th century, a multidisciplinary approach was strongly advocated for managing cases involving complex dental needs (Kokich, 1997). With the advent of digital diagnostic tools, enhanced communication systems, and collaborative treatment planning platforms, the predictability and efficiency of such interdisciplinary care have significantly improved. Orthodontic intervention

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plays a pivotal role in positioning teeth to complement future restorative procedures, ensuring preservation of dental structures while simultaneously addressing esthetic concerns.

However, the inherent complexity of merging orthodontic and prosthetic disciplines presents challenges—particularly in treatment sequencing, communication among specialists, and case-specific customization. Overcoming these barriers requires a structured, principle-driven planning model that fosters collaboration and ensures patient-centered care.

Drawing on the systematic methodologies proposed by Ray Dalio, five interdisciplinary principles have been adapted to streamline decision-making and enhance coordination in orthodontic-restorative treatment planning (Dalio, 2018). These principles not only guide clinical logic but also serve as a safeguard against treatment inconsistencies.

1. Core Principles Guiding Interdisciplinary Orthodontic and Restorative Therapy

A successful interdisciplinary approach relies on adherence to the following five core principles:

1. **Collaborative Planning with Active Participation**: Effective interdisciplinary treatment begins with input from both clinicians and patients, establishing shared goals and clearly defined expectations from the outset.
2. **Functional and Aesthetic Integration**: The treatment plan must harmonize aesthetic objectives with functional occlusion to achieve long-term stability and patient satisfaction.
3. **Predictive Digital Simulations**: Advanced planning tools, including digital mock-ups and 3D treatment simulations, are employed to visualize outcomes and refine the treatment sequence.
4. **Phased, Sequential Execution**: Treatments are organized into structured stages according to dental, skeletal, and soft tissue conditions, allowing each discipline to contribute optimally.
5. **Sustained Communication throughout Treatment**: Transparent and consistent communication among all members of the clinical team—and with the patient—is maintained throughout the process to minimize risk and enhance coordination.

2. Structured Workflow in Interdisciplinary Treatment Planning

To operationalize these principles, interdisciplinary orthodontic-restorative planning typically follows a four-phase workflow:

1. **Comprehensive Examination**: Initial clinical evaluation includes both subjective components (patient concerns, expectations, compliance potential) and objective assessments (intraoral and extraoral findings, caries risk, periodontal condition, and occlusal relationships).
2. **Diagnostic Data Integration**: A wide array of diagnostic records—ranging from 2D photographs and video footage to 3D digital scans and radiographic data—are compiled and analyzed to develop an accurate diagnosis.
3. **Problem Identification and Goal Setting**: Based on the clinical findings, a case-specific list of problems is defined, followed by a formulation of measurable, phased treatment goals (Grembowski, 1991).
4. **Implementation and Monitoring**: The interdisciplinary treatment plan is applied in stages, with scheduled re-evaluations and coordinated communication among specialties and with the patient.

3. Comprehensive Clinical Examination

A thorough clinical examination marks the foundational step in interdisciplinary orthodontic-restorative treatment planning. It comprises both subjective insights—rooted in the patient's concerns, expectations, and treatment compliance—and objective assessments involving structured evaluations across all three anatomical planes.

- **Sagittal plane**: Analyze molar and canine relationships, overjet, and maxillomandibular alignment.
- **Vertical plane**: Assess overbite and vertical proportions.
- **Transverse plane**: Evaluate midline deviations and anterior/posterior crossbites.

Caries risk and periodontal health must also be appraised to determine the viability of orthodontic intervention (American Dental Association, 2024; Dalio, 2018).

A detailed occlusal evaluation includes:

- Inter- and intra-arch contacts

- Anterior guidance (Schuyler, 2001)
- Fremitus and mobility
- Tooth position anomalies (rotation, impaction, overeruption)
- Occlusal planes (Spee and Wilson)
- Discrepancies between centric occlusion and maximum intercuspation (DiBiase, 2001; Kerosuo, 1995)

A structured checklist for these parameters enhances clinical consistency and sequencing logic.

4. Diagnostic Records and Aesthetic Considerations

A precise and multidisciplinary treatment strategy requires the integration and thorough interpretation of comprehensive diagnostic records. These records, which form the foundation of accurate diagnosis and planning, are typically categorized into five main groups:

1. Three-Dimensional Records Include digital intraoral scans, CBCT or conventional radiographs mounted on articulators using facebows or centric relation records, as well as physical study casts.
2. Video Recordings Capture real-time functional parameters such as lip mobility, speech articulation, and spontaneous smiling dynamics.
3. Two-Dimensional Photographs Standardized extraoral and intraoral images are used for symmetry analysis, arch form evaluation, and profile assessment.
4. Patient Questionnaires Structured forms assessing lifestyle behaviors, sleep quality, diet, and other behavioral factors that may influence treatment planning.
5. Consultation and Medical Reports Includes external letters from medical professionals, sleep studies, or interdisciplinary correspondence.

These datasets must be collectively reviewed by the interdisciplinary team. Beyond structural considerations, aesthetic diagnostics—including smile line evaluation, tooth dimension ratios, and Bolton analysis—play a crucial role in refining the treatment plan.

4.2.Aesthetic Parameters in Smile Design

Three key categories determine ideal smile esthetics:

1. Facial Parameters

- Facial Symmetry and Midline Alignment: The maxillary central incisors should ideally align with the facial midline (Sarver, 2007).
- Lip Dynamics: The position of the upper lip at rest and during smiling influences gingival and incisal display.
- Smile Arc: The incisal curve of the upper teeth should harmonize with the curvature of the lower lip (Frush, 1958).
- Demographics: Greater incisor visibility is generally preferred in younger and female patients, with a more conservative display favored in older or male individuals (Vig, 1978).

2. Mucogingival Parameters

- Gingival Exposure: A display of 1–2 mm gingiva above central incisors is considered esthetically optimal (Hunt, 2002).
- Gingival Margin Symmetry: Ideal cases feature horizontally aligned gingival margins for central incisors and canines, with laterals slightly apical (Sarver, 2007).
- Smile Line Considerations: In patients with high lip lines and anterior tooth loss, restorative challenges increase.
- Tissue Architecture: Severe hypodontia can result in soft tissue deficiency, complicating prosthetic integration (Khalaf & Wong, 2006).

4.3. Dental Parameters

- Tooth Characteristics: Esthetics depend on the harmonious integration of tooth size, shape, alignment, surface texture, and color (Levin, 1978).
- Proportional Balance: In hypodontia or microdontia, spacing often requires orthodontic redistribution prior to restoration.
- Golden Ratio (1:1.618): While sometimes used to guide anterior proportions, its routine application is controversial due to anatomical and cultural variability (Sarver, 2007; Magne, 2003; De Castro, 2006).
- Measurement Strategy: Perceived tooth width should be measured via frontal photographic analysis rather than intraoral methods, especially given arch curvature.

4.4. Clinical Implications

Relying strictly on numerical guidelines like the golden ratio can result in unnatural esthetic outcomes. Instead, treatment should be individualized—grounded in patient-specific anatomical features, esthetic expectations, and cultural considerations. Esthetic decisions should aim for natural harmony rather than formulaic perfection, supported by thorough diagnostic evaluation.

5. Treatment Planning: Problem Identification and Objective Structuring

A critical component of interdisciplinary orthodontic-restorative care is the systematic identification of clinical discrepancies. The process begins with the formulation of a detailed problem list, which highlights deviations from functional or aesthetic norms. This list serves as a blueprint from which targeted, measurable treatment objectives are derived.

In integrated orthodontic-restorative planning, two overarching goals define treatment direction: achieving aesthetic harmony and establishing functional occlusion. The latter is generally interpreted through the lens of *mutually protected occlusion*, wherein stable, simultaneous bilateral contacts are established in the posterior segments while the condyles reside in a musculoskeletally stable position. Functional forces are directed along the long axes of the teeth, and the anterior segment provides guidance and protective separation during excursive movements.

To visualize and refine treatment strategies, simulation tools are routinely employed prior to intervention. These may take the form of traditional wax-ups or contemporary digital mock-ups (Kesling, 1945; Hou et al., 2020). By previewing potential outcomes, clinicians can adjust orthodontic and restorative phases to align with functional and cosmetic targets.

Recent advancements in digital dentistry have expanded simulation capabilities, enabling clinicians to design multiple scenarios rapidly and with high precision. Orthodontic simulation software excels at modeling tooth movements but typically lacks restorative-specific functionalities such as prosthetic contouring. Conversely, restorative platforms (e.g., ExoCAD, Digital Smile Design) are optimized for prosthetic planning but do not support dynamic orthodontic adjustments.

Therefore, in most interdisciplinary workflows, simulation begins within orthodontic software to model movement and spacing, and digital data are subsequently transferred to restorative platforms to finalize prosthetic elements. This dual-software strategy ensures comprehensive visualization of both treatment components.

However, for a simulation to be clinically meaningful, it must be preceded by:

- A thorough clinical examination
- Comprehensive diagnostic record review
- A collaboratively constructed problem list
- Clearly defined, realistic treatment objectives

Failure to establish these elements before simulation can result in misaligned treatment expectations, redundant planning steps, or compromised outcomes. Efficient, evidence-based planning thus depends not only on digital tools, but also on clinical insight and interdisciplinary consensus.

6. Implementation of the Treatment Plan and Interdisciplinary Communication

The execution phase of interdisciplinary orthodontic-restorative care is grounded in the priorities established through diagnostic evaluation and problem list formulation. Treatment sequencing is tailored to the final restorative objectives, with orthodontic interventions often preceding prosthetic steps to ensure optimal spatial and structural alignment.

Depending on the individual case, restorative interventions may be necessary:

- Before orthodontics (e.g., provisional build-ups to influence tooth movement),
- During treatment (e.g., management of space distribution),
- Or following orthodontics (e.g., reshaping, restoring natural form, or prosthetic replacement of missing teeth).

Typical restorative strategies integrated at various treatment phases are summarized in Table 1.

As orthodontic therapy approaches completion, the original pre-treatment checklist should be revisited to verify whether defined goals—both aesthetic and functional—have been achieved. This ensures alignment between initial planning and final outcomes.

Central to this phase is effective communication. Coordination among the orthodontist, restorative dentist, and other involved specialists—both at the planning stage and during each procedural transition—is essential. Miscommunication at any point may lead to duplicated efforts, extended treatment time, or suboptimal results. Therefore, structured team meetings and shared documentation systems are strongly recommended throughout the course of care.

Table 1. The treatment planning process.

Patient Factors	Orthodontic Factors	Dental Factors	Soft Tissue Factors
- Patient requests - Medical history - Development stage - Oral hygiene - Patient age (growth stage) - Cost -Concern of invasive procedures	- Skeletal pattern - Tooth/tissue ratio -Overbite crowding/ distance - Overjet - Need for anchors	- Tooth shape/size - Alveolar crest width	- Gingival biotype - Lip line

7. Space Management in Cases of Hypodontia or Tooth Size Discrepancy

In cases involving congenitally missing teeth or significant size discrepancies (e.g., microdontia), space management becomes a key decision-making component. The interdisciplinary team must determine whether to:

- Close the space orthodontically, creating a natural, gap-free arch form; or
- Maintain or open the space, enabling prosthetic replacement of the missing tooth or reshaping of adjacent teeth.

This decision is influenced by multiple clinical, skeletal, and esthetic parameters. In cases where microdontia is present, space redistribution may be necessary before final restorative procedures can be performed. The approach must balance occlusal harmony, facial esthetics, periodontal health, and long-term prosthetic viability.

The clinical criteria that guide this decision-making process are outlined in Table 2.

Table 2. Factors influencing the decision to open or close the space.

Open the Space Orthodontically	Close the Space Orthodontically
Cases with class 3 skeletal pattern Cases without crowding of the dentition Large discolored canines are present Aesthetic demands of the patient Stable class 1 buccal segment Hypodontia located in the quadrant jaw Premolars in the same mandible with a poor long-term prognosis Unilateral lost or missing lateral tooth Cases where canine tooth guidance is desired to be maintained	Class 2 skeletal pattern Crowding requiring extraction Small light-colored canine Missing lateral incisors (preservation of symmetry)

8. Closing the Space: Canine Substitution for Missing Maxillary Lateral Incisors

In cases where the maxillary lateral incisors are congenitally absent, one frequently employed approach is orthodontic space closure via canine substitution. In this technique, the maxillary canine is moved mesially to occupy the lateral incisor position, while the first premolar assumes the canine role in the arch (Armbruster et al., 2005; Louw & Evans, 2007; Zachrisson, 2011).

However, this repositioning requires significant morphological and esthetic modifications to both the canine and the first premolar in order to simulate the appearance and function of the teeth they are replacing. The canine, in particular, presents several challenges when substituted for a lateral incisor:

- Increased mesiodistal and buccopalatal width
- Greater crown length
- More coronal gingival margin
- Pronounced labial contour
- Typically darker enamel shade

To overcome these discrepancies and achieve a natural appearance, selective enamel reduction and crown reshaping are essential. This can be performed before or during the orthodontic phase, typically using fine-grit diamond burs and abrasive discs under water-cooled conditions. Enamel reduction is usually concentrated on the distal surface, which is naturally more convex, to reduce width and enhance incisor-like morphology (Tuverson, 1970; Zachrisson, 1975).

Studies have shown that maxillary canines may exceed lateral incisor width by 1.0–1.5 mm (Tuverson, 1970; GC, 1993), necessitating targeted enameloplasty. Reduction on the mesial, distal, and labial surfaces may be indicated in select cases to harmonize form and occlusion. Importantly, controlled enamel reduction has not been associated with long-term pulpal damage when performed judiciously (Zachrisson, 1975).

To address postoperative dentinal sensitivity, topical fluoride varnish—such as Duraphat®—should be applied to the treated surfaces. While irreversible, this method is considered safe and effective when applied with precision and careful case selection.

The indications, benefits, and limitations of canine substitution as a space closure method are summarized in Table 3, while Figure 1 illustrates crown modification zones.

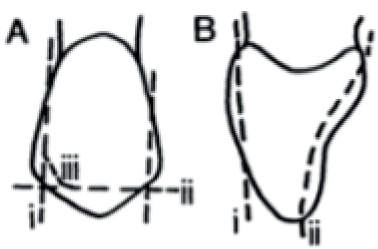

Figure 1. Modification of canines with grinding (A) (i) Interproximal reduction should be greater distally to flatten the natural distal projection of the canine. (ii) The tip of the canine should be reduced to a level slightly shorter than the central incisor. (iii) Incisal angles should be rounded, distal more than mesial. (B) (i) Reduction of the labial surface. (ii) Reduction of the palatal surface.

Table 3. Advantages and disadvantages of space closure. adapted from zachrisson et al. (Zachrisson B, 2011)

Advantages of Space Closure	Disadvantages of Space Closure
• Permanence of the finished result and the ability to complete treatment in early adolescence due to a simpler restorative approach • Early mesial movement of the canine tooth preserves the alveolar bone height in that area • It can eliminate the need for prosthetic dental treatment. • Minimally invasive resin restorations interfere less with the dental tissues. • Excellent aesthetic results can be achieved using modern restorative techniques. • It can be accepted by patients.	• The timing of orthodontic and restorative treatments should be determined very carefully considering the possibility of relapse. The tendency for the space to reopen should not be ignored. Keeping the teeth in the same position is very critical. • When the teeth are brought closer together in the anterior region, it may cause deviations in the upper incisor inclinations, and it also flattens the profile appearance. • The forms of the canines may not be suitable for aesthetic modification in some cases. • The dental arch narrows, which may cause dark buccal corridors when smiling. • Group function may occur in laterotruv movements or the functional occlusion requiring guidance in the first premolars may change. • Resin-based restorations may fail over time and must be kept under control, requiring routine maintenance and polishing.

In cases where maxillary canines are substituted for missing lateral incisors, morphological discrepancies such as increased crown width, darker color, and prominent labial ridges must be addressed. If enamel reduction alone does not yield satisfactory esthetic results, composite additions offer a conservative alternative (Figure 2). In select cases, ceramic veneers may be more appropriate depending on esthetic expectations.

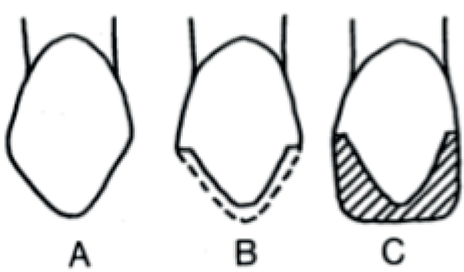

Figure 2. Modification of canines by composite additions. (A) Unmodified canine. (B) Reduction of half of the enamel thickness from the incisal third of the canine. (C) Composite added to reshape the canine to resemble an incisor.

These modifications are ideally performed during active orthodontic treatment—either pre-bonding or mid-treatment—so that tooth positions can be coordinated with the restorative contour, and space closure adjusted accordingly. Delaying contour correction until the end of treatment may complicate masking the canine's natural form.

Because canines often have a pronounced palatal cingulum and convex labial profile, their buccopalatal thickness should be reduced to avoid occlusal interference and exaggerated prominence. Enamel reduction, especially on the distal and labial surfaces, also helps refine crown shape and reduce width (Tuverson, 1970). Studies show that moderate reduction (1–1.5 mm) is safe and does not compromise pulpal health (Zachrisson, 1975). When enamel is thinned, the darker dentin may become visible, necessitating tooth whitening. Topical fluoride (e.g., Duraphat®) should be applied after grinding to prevent sensitivity.

If gingival margins are asymmetrical, orthodontic extrusion of the canine can lower the gingival zenith to align with central incisors. Simultaneous incisal edge reduction minimizes occlusal interference and supports a harmonious smile arc (Rosa, 2001).

When first premolars are used to mimic canines, bracket placement is essential. A slight distal offset induces mesial rotation, helping to conceal the palatal cusp and expand mesiodistal width (Zachrisson, 1975). Crown height discrepancies can be managed via vertical bracket positioning. Intrusive placement brings the gingival margin apically and repositions the palatal cusp, but may require occlusal restoration (Figure 3). Alternatively, gingival bracket placement extrudes the premolar, which may improve esthetics in low-smile-line patients, but could necessitate gingivectomy in high-smile-line cases.

In both strategies, the palatal cusp may require selective grinding to prevent occlusal conflict. If more buccal prominence is desired, controlled buccal torque can be applied, though care must be taken to avoid root displacement.

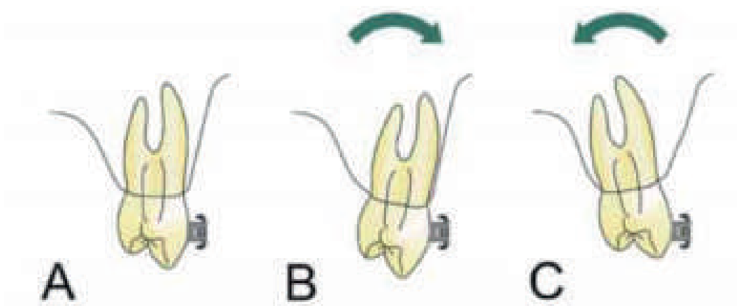

Figure 3. Shows the effects of changing the vertical position of an orthodontic bracket placed on the first premolar. (a) Bracket in the correct position for the maxillary first premolar. (B) Bracket placed in a more gingival position, resulting in extrusion of the tooth and some degree of buccal root torque. (C) Bracket placed in a more incisal position, resulting in intrusion of the tooth, which in turn causes some degree of palatal root torque, vertically lowering the palatal cusp. Permanence of the finished result and the ability to complete treatment in early adolescence due to a simpler restorative approach.

9. Opening the Space

The amount of space to be created for a missing anterior tooth—particularly a maxillary lateral incisor—is determined by a combination of occlusal relationships, tooth size proportions, and esthetic requirements. From an esthetic perspective, the space required for a lateral incisor is influenced by the width of the contralateral lateral incisor and the dimensions of the adjacent central incisors. In general, the lateral incisor should approximate two-thirds the width of the central incisor, a proportion commonly referenced in smile design and sometimes linked to the "golden ratio" (Schuyler, 2001).

In many cases, the opposing lateral incisor is peg-shaped, making symmetry more difficult to achieve. Therefore, treatment planning should involve both the creation of adequate space for the missing tooth and the restoration of ideal dimensions for the peg-shaped contralateral incisor. Attention must also be given to maintaining the dental midline, which plays a pivotal role in facial esthetics and occlusal balance.

In individuals with peg-shaped lateral incisors, composite build-ups are often the preferred method for reshaping. This conservative technique allows the tooth to be restored to a more natural size with minimal invasiveness. To optimize restorative outcomes, the orthodontist should position the lateral incisor centrally within the allocated space, so that composite can be applied symmetrically on both the mesial and distal surfaces. This enhances the emergence profile, crown contour, and anatomical proportions (Figure 4).

Despite its benefits, restoring a peg-shaped lateral incisor presents challenges. Anatomical inconsistencies between the root structure, cervical margin, and crown size may increase the risk of stress concentration at the cervical region following restoration. This may predispose the tooth to marginal fractures or compromise the longevity of the composite restoration.

If there is a greater need for space redistribution in the maxillary arch, extraction of peg-shaped lateral incisors may be indicated. In such cases, bilateral extraction helps preserve midline symmetry. This option is particularly effective when implemented before the eruption of maxillary canines, allowing the canines to drift into the lateral incisor position naturally and be later modified esthetically.

However, if the peg-shaped incisors do not pose significant esthetic or functional concerns, and if occlusion remains stable, leaving them untreated may also be a viable option, particularly in patients with low esthetic expectations or limited restorative demand.

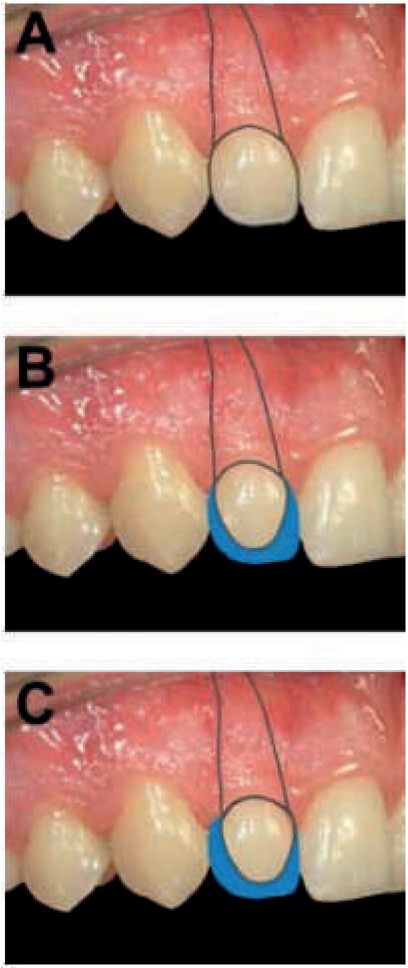

Figure 4. Proper Alignment of the Peg-Shaped Lateral Incisor Before Composite Build-Up (A) Ideal Aesthetic Proportions: A harmonious restoration of a lateral incisor requires adherence to proportional width-to-height relationships that are consistent with adjacent teeth, especially the central incisor and canine. Achieving this balance is key to establishing a natural and esthetically pleasing appearance. (B) Centrally Aligned Peg-Shaped Lateral Incisor: When the peg-shaped lateral is accurately positioned in the center of the edentulous space, composite can be symmetrically distributed on both the mesial and distal surfaces (indicated in blue). This facilitates an anatomically correct emergence profile and optimizes esthetic integration with adjacent teeth. (C) Mesially Mispositioned Peg Lateral: If the tooth is placed too close to the central incisor, restorative space becomes uneven. As a result, composite must be disproportionately added to the distal surface (indicated in blue), leading to an imbalanced contour. This

may compromise esthetics and result in a convex ridge prone to plaque accumulation, thereby affecting both function and hygiene.

Conclusion

Successful orthodontic-restorative treatments rely on seamless interdisciplinary collaboration. Strategic task distribution among team members, along with consistent and clear communication, is essential at every stage of care. Coordinating the timing and sequencing of orthodontic and restorative phases not only improves treatment efficiency but also enhances both functional stability and esthetic outcomes. When planned and executed in harmony, interdisciplinary approaches offer patients a comprehensive path toward long-term oral health and satisfaction.

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Chapter 4

Multidisipliner Approach in Orthodontics and Endodontics

Kübra Aslantaş Akar[1]

Abstract

Orthodontics and endodontics are two significant and complementary fields of dentistry. Orthodontics focuses on the proper alignment of the teeth aesthetically and functionally, whereas endodontics deals with the health, pathology, and treatment of the dentin-pulp complex. The application of orthodontic forces causes inflammatory effects on the periodontal ligament and pulp. Therefore, the patient's oral tissues must be ensured to be completely healthy prior to orthodontic treatment. Close monitoring of pulp health during orthodontic treatment is crucial to maintain pulpal vitality, increase the mechanical resistance of the teeth, and ensure their long-term survival.

Furthermore, management of dental trauma should be a priority to preserve pulpal vitality. In such cases, appropriate orthodontic approaches and treatment plans should be developed. By offering a specialized treatment alternative for immature teeth, regenerative endodontics promotes pulpal and periodontal dental health. In orthodontic treatment planning, it is essential to precisely ascertain orthodontic force parameters while considering the patient's distinctive characteristics. In this process, a multidisciplinary approach is vital to achieve optimal results for patients, relatives of the patients, and physicians.

1. Introduction

Orthodontics and endodontics are two fields of dentistry that focus on different aspects of oral and maxillofacial health. Orthodontics is a field focused on enhancing the aesthetics and functionality of the teeth, jaws, and their interrelationship. Endodontics pertains to the biology, pathology, and

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regeneration of the dentin-pulp complex and periodontal tissues, aiming to preserve dental health through the diagnosis, prevention, and treatment of diseases and injuries affecting these tissues. This section of our book will analyze the intricate relationship between these two fields and highlight the significance of collaboration in multidisciplinary treatments.

1.1. Relationship between Orthodontic Force and Periodontium

Orthodontic tooth movement happens because of inflammation in the periodontal ligament (PDL) and alveolar bone when orthodontic forces are applied to the crown of the tooth using various attachments (Turner & Pavalko, 1998). According to Burstone, orthodontic tooth movement occurs in three phases:

1. Initial Phase: This phase, which starts with the compression of the PDL with the force applied to the tooth and the rapid movement of the tooth in the alveolar socket, occurs within 24 hours to 2 days. Cells and vessels sustain damage during this process, leading to the formation of hyalinized (cell-free, glassy) tissues.
2. Pausing Phase: In the second phase, the tooth movement is observed minimally or not at all.
3. Movement Phase: Tooth movement gradually increases. Hyalinization and indirect bone resorption occur in conjunction with each other (Smith & Burstone, 1984).

We expect orthodontic tooth movement to occur at optimum orthodontic force levels by stimulating cellular activity without interrupting the PDL blood supply(Burstone, 1989). However, depending on the type and intensity of orthodontic movement, the periodontium is subjected to different types of stress. In particular, forces that don't evenly compress the PDL may cause problems like tissue damage, root loss, or death of the tissue (Lin et al., 2023). Furthermore, if orthodontic forces cause compression of the blood vessels of the periodontium, this may result in a direct reduction in pulpal blood flow(Sabuncuoglu & Ersahan, 2014).

1.2. Relationship between Orthodontic Force and Dentin-Pulp Complex

The dental pulp is a specialized connective tissue surrounded by dentin with a rich vascular and nerve network (Goldberg et al., 2011). The four main functions of the pulp are nutrition, innervation, protection, and formation (Sloan & Smith, 2007). Although the pulp is richly vascularized, its connection to the surrounding tissues is through the blood vessels of the periodontium passing through the apical foramen as it is surrounded by dentin. Thus, changes in periodontal blood flow or vascular tissue pressure affect the health status of the dental pulp (Hamilton & Gutmann, 1999).

Orthodontic pressures can induce changes on the pulp that vary from mild hyperemia to complete pulp necrosis (Reitan, 1960). This variation is caused by the variability of the intensity and duration of the applied orthodontic force, as well as the type, direction, and distribution of orthodontic movement (Krishnan & Davidovitch, 2006).

The primary effect on the pulp caused by orthodontic forces is a reduction in pulpal blood flow, leading to hypoxia and affecting the levels of inflammation-related enzymes and neuropeptides (Huokuna et al., 2023). Increased protein levels such as CGRF, SP, VEGF indicate that orthodontic force leads to mild inflammation in both the periodontium and the pulp (Caviedes-Bucheli et al., 2021). Another effect of orthodontic forces is that they can reduce tooth sensitivity because of a lack of oxygen in the nerve tissues of the pulp, which can result in altered responses during sensory tests like the electric pulp test(Butt & Harris, 2022; Huokuna et al., 2023). However, most of these reactions are acute reactions observed within the first few days to a week and are usually reversible (Consolaro & Consolaro, 2018).

Fibrotic tissue formation, pulp calculus formation, and reduction in pulpal volume are other histomorphologic changes that can be observed in the pulp with the implementation of orthodontic forces. (Lazzaretti et al., 2014).

2. Endodontic Factors in the Orthodontic Treatment Process

2.1. Endodontic Evaluation Before Orthodontic Treatment

Oral tissues should be completely healthy before orthodontic treatment. This condition requires a detailed anamnesis and examination process before orthodontic treatment, as in all branches of dentistry. In the clinical examination, the health of the pulp, dental anomalies, and the status of existing restorations should be examined; the presence of suspicious teeth and/or restorations should be evaluated; and basic health criteria such as periodontal pocket measurements, dental mobility, and the presence of gingival bleeding should be reviewed (Proffit et al., 2012). Thermal and electrical pulp tests should be performed to assess the health status of the pulp. Past dental traumas should be carefully evaluated for potential damage such as missed root fractures, ankylosis, and root resorption, and care should be taken to obtain a detailed dental history from the patient/caregiver (Owtad et al., 2015). The current situation should be recorded with forms and intraoral and extraoral photographs (Lacombe et al., 2021). Radiographic examination should include periapical lesions, root resorption, dental fractures, and trauma history of hard tissues; dental caries (white spot lesions, enamel, and dentin caries); and the presence of healthy/unhealthy restored teeth and root structure (Bayram et al., 2011). Radiographs can also provide information about the health of the periodontal ligament, the presence and size of periodontal pockets, and the health status of the periodontium by monitoring lateral or apical lesions.

The prevalence of dental caries is decreasing globally, but the attachments used in orthodontic treatment are considered a strong risk factor for dental caries as they are considered a predisposing factor for plaque accumulation and demineralization (Cruz & Edelstein, 2016; Jin et al., 2016). During orthodontic treatment, the early diagnosis and treatment process may be interrupted as caries detection may become difficult (Tufekci et al., 2011). Therefore, prior to orthodontic treatment, the clinician should make patients aware of oral hygiene, plaque control, and elimination by performing preventive and invasive dental treatments.

Orthodontic force may generally lead to undesirable effects on the dentin-pulp complex, even temporarily. However, preserving pulp vitality increases mechanical resistance and long-term survival of teeth (Vitali et al., 2022). Therefore, pulp health must be closely monitored before, during, and after orthodontic treatment. The pulp vitality must be recorded before orthodontic treatment, dental symptoms, if any, should be reviewed, and appropriate treatments should be performed (Rathi & Rathi, 2023). The dental health during orthodontic treatment must be regularly monitored by radiographs taken from the patients.

It is known that exposure of endodontically treated healthy teeth to orthodontic forces does not increase the risk of root resorption, nor does orthodontic movement provide a protective effect against resorption and thus does not require a special orthodontic approach(Beck et al., 2013).

2.2. Management of Endodontic Emergencies During Orthodontic Treatment

Mechanical compression of the PDL induced by orthodontic pressures may lead to reduced pulpal blood flow and hypoxia. This condition causes mostly reversible effects on the pulp, but in the case of heavy forces or trauma history, it may lead to irreversible pictures (Huokuna et al., 2023). Diagnosing endodontic treatment during the orthodontic treatment process brings some special circumstances. For example, it may be required to take radiographs of the suspicious tooth without superposition of the attachments or to remove the orthodontic attachments to perform pulp sensitivity tests without obtaining erroneous results due to the attachments. The same is also applicable for effective rubber dam isolation and proper cavity preparation, regardless of the endodontic treatment option (Beck et al., 2013).

As it is known that the inflammatory process will resolve within 15 to 30 days after the endodontic treatment is completed, there is no harm in re-exposing these teeth to orthodontic force at the end of the process (Consolaro & Consolaro, 2013). Therefore, unless we observe external apical root resorption, endodontic treatment of teeth with undiagnosed periodontitis does not require a special approach (Chen et al., 2024). Conversely, teeth with inflammatory lesions requiring endodontic treatment require a meticulous approach to both endodontic and orthodontic treatment. It should be noted that orthodontic forces will affect unhealthy periodontal tissues even if they are within physiological limits(Bakkari, 2022). In this process, the timing and intensity of orthodontic forces to be applied to the tooth should be controlled following the effective treatment of the lesion by removing the relevant tooth from orthodontic treatment, and endodontic lesion follow-up should be performed more frequently compared to teeth without orthodontic treatment (Consolaro et al., 2020; Zhao et al., 2023).

In the event that periodontal lesions do not heal or progress, the tooth should be removed from orthodontic treatment; the presence of additional or accessory canals, crown anomalies such as dens invaginatus, and the possibility of extraradicular infection should be evaluated. This is because it has been reported that orthodontic forces do not affect the biology or virulence of the lesions, so orthodontic treatment can be continued following the inflammatory process after effective lesion treatment is provided (Consolaro et al., 2020).

2.3. The Effect of Orthodontic Movement on Root Resorption

External cervical root resorption is caused by the destruction of cementum tissue, leading to the interaction of clastic cells of the periodontium and dentin. Its etiology is not fully understood, but orthodontic treatment, history of dental trauma, and hypoxia are the most commonly associated factors. Pathogenesis consists of 3 phases: initial, resorptive, and reparative. In the initial phase, the pulp is vital and not yet affected. In this phase, the patient is clinically and radiographically asymptomatic (Mavridou et al., 2017). In the later phases, the pulp cannot be protected from resorption, and a formation of vascular granulation tissue leads to the formation of an appearance called 'pink spot' in the crown, and cavitation in the root may be observed in the continuation of the clastic process (Heithersay, 2004). While the radiographic image appears as a radiolucent area during the resorption phase, radiopaque traces are attached to it with the onset of the reparative phase (Gunst et al., 2013). Although resorption is often irregular by its nature, there are well-marginated cases (Patel et al., 2022). Observing cavitation of the root makes it difficult to distinguish from internal root resorption (Patel et al., 2018). Therefore, the use of cone beam computed tomography is recommended by the European Society of Endodontics to facilitate the diagnosis of external root resorption (Patel et al., 2019).

External root resorption is regarded as one of the side effects of orthodontic treatment (Sondeijker et al., 2020). Mechanical risk factors for the formation of external root resorption include the magnitude, direction, and duration of orthodontic force, whereas biological risk factors include age, gender, history of traumatic injury, presence of periapical lesions, root morphology, previous root resorption, bone density, type of malocclusion, individual susceptibility, and genetic predispositions (YILDIRIM et al., 2025).

The relationship between the magnitude of orthodontic force and root resorption: As the magnitude of the applied force increases, the risk of periodontal tissue hyalinization and resorption increases (Wahab, 2017).

The relationship between the direction of orthodontic force and root resorption: Studies have indicated that strong forces, particularly when pushing teeth down or tilting them, create more pressure at the root tip and lead to more root resorption than other types of orthodontic forces (Bakkari, 2022; Chiqueto et al., 2008).

The relationship between duration of orthodontic force and root resorption: Long-term and continuous forces concentrated on the tooth increase the risk of root resorption, while short-term or intermittent forces lead to less resorption (Bakkari, 2022).

Demographic factors have significant effects on root resorption. Age is the main factor determining this relationship, whereas an increase in root volume is observed in young individuals, especially in immature teeth; the risk of root resorption is higher in adults. Root resorption rates in certain teeth (maxillary lateral, maxillary canine, and mandibular canine) are higher in women than in men. According to reports, bite anomalies like open bite and deep bite increase the risk of root resorption (Lin et al., 2025).

When root resorption arises during orthodontic treatment, the clinician must carefully evaluate whether to continue treatment, taking into account the risk of resorption progression. Continuation, modification, or termination of treatment are among the clinician's options (Sondeijker et al., 2020). In making this decision, existing occlusal problems (deep bite, occlusal trauma) and the patient's aesthetic concerns should be considered. For example, if there are long-term negative effects of occlusal trauma, it may be more appropriate to continue treatment or to remove the orthodontic force on the affected teeth (Danz et al., 2014). In case of generalized severe root resorption, orthodontic treatment should be terminated. However, if treatment is planned to continue, it has been recommended that it be interrupted for at least 3 months to allow the resorptive lacunae to heal (Mehta et al., 2017).

It is recommended during the follow-up period that radiographic evaluation should be performed 6 months after the treatment is restarted, passive retention appliances should be used after the treatment, and these appliances should not create any force on the tooth. In teeth with root resorption of 2 mm or more, the remaining root length and mobility level should be carefully monitored, periodontal examinations should be performed regularly, and the patient should be informed about oral hygiene (Sondeijker et al., 2020).

Although root resorption is often asymptomatic, endodontic evaluation may be required when pulpal pain or pulpitis symptoms are observed (Ahangari et al., 2015). Therefore, the multidisciplinary approach of the orthodontist and endodontist together has a critical role in the survey of the teeth to protect the teeth at risk.

3. Endodontic-Orthodontic Multidisciplinary Approach in Dental Trauma

Traumatic dental injuries (TDI) mainly occur in children and young adults and account for 5% of all traumas. Up to 25% of school-age children experience a dental injury. In adults, it occurs in 33% of the population, most of whom are younger than 19 years of age. While luxations are the most frequent dental injuries in deciduous dentition, crown fractures are more common in permanent teeth. Correct diagnosis, treatment planning, and follow-up are crucial for a favorable healing process. It should be considered that teeth with a history of dental trauma will be affected more than healthy teeth in terms of pulpal and periodontal complications during the diagnosis phase. Therefore, pulp sensitivity tests should be applied to evaluate the vitality of the tooth, and a comprehensive clinical examination should be performed in line with the type and severity of the trauma (Levin et al., 2020). Periapical radiographs should be taken in a parallel technique for teeth with a history of trauma before, during, and after orthodontic treatment. Additionally, the clinicians might use more advanced imaging methods like cone beam computed tomography (CBCT) if they think there is external root resorption (Sandler et al., 2021).

Preservation of pulpal vitality and periodontal health should be a top priority in acute trauma cases. The patient and the patient's relatives should be informed about the treatment procedure, possible complications, home care, and follow-up process, and informed verbal and written consent should be obtained prior to treatment. It is necessary to refer to the guidelines developed by the International Association of Dental Trauma (IADT) on emergency management and possible treatment options (Levin et al., 2020).

Prior to orthodontic treatment of traumatized teeth, the patient/parent should be apprised of the potential risks of root resorption, pulp necrosis, and infection. The clinician should generally take care to move with light forces during the treatment process of traumatized teeth. Thermal nickel-titanium archwires should be preferred, especially at the beginning of the treatment process or when aligning newly traumatized teeth. Additionally, radiographic evaluation and pulp sensitivity tests should be performed at frequent and regular intervals during the treatment (Sandler et al., 2021).

Orthodontic management of traumatized teeth depends on the type of trauma. According to the orthodontic management of traumatized teeth classification guide, minor periodontal damage (concussion and subluxation), moderate-severe periodontal damage (lateral-extrusive-intrusive luxation and avulsion), crown and crown/root fracture, root fractures, root canal-treated teeth due to trauma, and endodontic difficulties (pulp obliteration, root resorption, ankylosis, autotransplantation, and regenerative endodontic treatment) (Sandler et al., 2021) (Table 1).

Table 1. Orthodontic management of traumatized teeth depends on the type of trauma

Immature traumatized teeth	Observe whether there is evidence of continued root growth on radiographs. Perform clinical and radiographic evaluation six months, one year, and two years after trauma.
Minor damage to the periodontium (Concussion and Subluxation)	(A concussion is an injury to the periodontal structure of the tooth without mobility or displacement. The tooth is usually sensitive to percussion, and there are no other symptoms.) (Subluxation is an injury that causes abnormal mobility of the periodontal structure of the tooth. The tooth is not displaced and is sensitive to percussion, with sulcular bleeding from the gingiva.) A three-month observation period is recommended to eliminate inflammatory root resorption.
Moderate/severe damage to the periodontium (Extrusion, Lateral Luxation, Intrusion, Avulsion)	(Extrusion: The tooth appears longer than its neighbor due to outward displacement, and it exhibits mobility. Reports indicate a significant loss of tooth vitality following this type of TDI. Lateral Luxation: The tooth is displaced in the palatal or lingual direction. The tooth may give a high metallic sound to mobility and percussion. Intrusion: A type of traumatic dental injury that displaces the tooth deep into the alveolar bone socket. It has reduced mobility and produces a high metallic sound on percussion. Avulsion: The tooth is completely displaced out of the socket. Such teeth may be replanted and splinted.) A one-year observation period is necessary to eliminate ankylosis. Orthodontic tooth movement can start only after the completion of periodontal healing, taking at least six months. If teeth are moved orthodontically between 6 and 12 months, a strong suspicion of ankylosis is considered, especially when tooth movement is not as expected.
Crown and crown/root fractures without pulpal involvement	A crown fracture is defined as a fracture involving enamel, dentin, and possibly pulp. A crown-root fracture is defined as a fracture involving enamel, dentin, cementum, and possibly pulp (complicated or uncomplicated fractures). An observation period of three months is recommended to eliminate inflammatory resorption.
Crown and crown/root fractures with pulpal involvement	Once radiographic evidence of vital pulp treatment and the hard tissue barrier is evident (approximately three months), orthodontic movement can begin.
Root fractures	A recommended observation time is one to two years, with a shorter duration advised for asymptomatic cases. Upon the completion of connective tissue healing, the coronal segment must be managed as if it were a short-rooted tooth, and the tooth should remain immobile until effective endodontic treatment and connective tissue healing of the coronal segment have occurred.

Teeth in need of endodontic treatment due to caries	In the absence of periapical pathosis, immediate orthodontic movement is recommended. Definitive obturation with gutta-percha is recommended instead of using calcium hydroxide in the root canal.
Teeth in need of endodontic treatment due to trauma	In mature teeth, following the initial calcium hydroxide dressing, a definitive obturation with gutta-percha should be placed. This conflicts with advice previously given by others. The observation period prior to orthodontic treatment should be one year to monitor healing and ankylosis. Routine radiographic monitoring every six months thereafter is recommended.
Pulp canal obliteration	This is not an indication for endodontic treatment as the tooth is still alive. Radiographic monitoring is recommended. We recommend light, short-acting forces if necessary. Whenever possible, it is useful to partially or completely exclude such teeth from orthodontic forces.
Resorption due to infection	Orthodontic treatment is started only when the infection is under control. A multidisciplinary team is recommended.
Teeth requiring endodontic treatment due to inflammatory resorption	Radiographic evidence of healing with an observation period of at least one year should be awaited before initiating orthodontic tooth movement; teeth with signs of root resorption are considered to be more susceptible during orthodontic treatment.
Replacement resorption	We recommend a multidisciplinary team for potential auto-transplantation or decoronation needs. Treatment goals should be limited. Pulp and root health records should be kept at baseline and during treatment. Forced luxation followed by orthodontic extrusion should be considered for final position alignment. The tooth should be left outside the archwire or used for anchorage.
Autotransplanted teeth	(Autotransplantation is a traditional method used in dentistry to reconstruct a functional tooth substitute and can provide an often overlooked treatment option in cases of hypodontia requiring orthodontic treatment) Orthodontic treatment can be started three to nine months after periodontal healing (approximately eight weeks) and before complete bone repair. Extrusion can be started earlier than rotational or bodily tooth movements. Ankylosis should be excluded when the tooth does not move as expected.
Regenerative endodontics/ revitalization techniques	Orthodontic treatment should be postponed until the results have stabilized with an observation period of at least two years.
Teeth with apical resection	Periapical lesions should demonstrate significant radiographic healing one year post-apicoectomy prior to the initiation of orthodontic therapy.

There are many factors involved in the etiology of traumatic dental injuries (TDI). Dentists need to advise patients and/or their parents about the risk factors associated with certain malocclusions. The vast majority of TDIs occur in children and in the maxillary anterior teeth. Increased overjet and upper lip insufficiency are the two main factors that increase the risk of such injuries (Wig et al., 2022). Consideration of these predisposing factors raises the issue of whether orthodontic intervention can help prevent dental trauma in individuals with malocclusion. The use of various functional fixed or removable orthodontic attachments at an early age may help the teeth and jaws to be more appropriately positioned and less susceptible to dental trauma. A Cochrane study concluded that providing early orthodontic treatment to children with prominent upper anterior teeth is more effective in reducing the incidence of incisal trauma than providing orthodontic treatment in adolescence (Batista et al., 2018). Another study found that starting orthodontic treatment early or using a two-step plan for children with prominent upper front teeth is better at preventing injuries to those teeth than waiting until adolescence to start treatment(Veitz-Keenan & Liu, 2019). Cobourne et al. concluded that while early treatment does not lead to improved overall outcomes compared to later treatment, early initiation of orthodontic treatment may prevent psychological trauma, even if it does not affect physical trauma, when the risk of dental trauma is actually increased or when a child is bullied because of his or her aesthetic appearance (Cobourne et al., 2022). Therefore, approaches that favor early orthodontic intervention to reduce the likelihood of physical and/or psychological trauma seem rational for now.

4. Relationship between Regenerative Endodontics and Orthodontic Treatment

Immature permanent teeth can lose their vitality for many reasons, including caries and dentoalveolar trauma (Banchs & Trope, 2004). The ideal outcomes in the treatment of immature teeth diagnosed with pulpal necrosis are to treat and/or prevent the recurrence of apical periodontitis, to promote the continuation of root growth interrupted by necrosis, and to restore the biofunctional competence of pulpal tissue (Hargreaves et al., 2008). REP with a biologically based perspective is not a fanciful approach but a successful alternative to traditional apexification procedures that aims to produce pulp-like tissue in the root canal cavity, provide revascularization, and relieve pain and inflammation by stimulating the migration of viable inflammation- and destruction-resistant stem cells in the periapical region, thus eliminating the need for foreign stem cell transfer(Diogenes et al., 2013; Dissanayaka & Zhang, 2020; Sonoyama et al., 2007).

In root canals filled with blood clots upon induction of periapical hemorrhage, blood-derived growth factors such as platelet-derived growth factor (PDGF), transforming growth factor (TGF), vascular endothelial growth factor (VEGF), insulin-like growth factor (IGF), and fibroblast growth factor (FGF) may facilitate angiogenesis by signaling to endothelial precursor cells and perivascular progenitor cells in periradicular tissues, and thus new vessel formation may occur in the root canal cavity along with other growing tissues (Civinini et al., 2011; Jung et al., 2019). Another advantage of periapical hemorrhage induction is the migration of SCAPs from the apical foramen into the root canal space. This eliminates the need for foreign stem cell transfer. Many studies have indicated that the use of a blood clot as a scaffold in REP is practical and successful (Flake et al., 2014; Nagy et al., 2014; Petrino et al., 2010). Nevertheless, the induction of periapical hemorrhage does not always result in a sufficient quantity of hemorrhage, which may lead to a scaffold matrix that is incomplete in terms of the content of blood clot signaling molecules, growth factors, and stem cells(Nosrat et al., 2021). In many histological studies in the literature, it has been observed that the induction of apical hemorrhage alone does not provide selective migration of apical papilla stem cells and consequently fails to regenerate the dentin-pulp complex, and contrary to expectations, the hard tissues formed in the root canals are organized as cementum or bone instead of dentin, and the soft tissue is organized as fibrous connective tissue or periodontal ligament instead of pulp (Arslan et al., 2019; Nicoloso et al., 2019; Torabinejad et al., 2017).

The need for directed regenerative endodontic procedures emerged from the goal of creating a dentin-pulp complex rather than repair (Galler et al., 2014). Tissue engineering in regenerative endodontic procedures is based on the use of the triple concept of stem cells, biomimetic scaffolds, and growth factors to treat pulp inflamed by infection, trauma, or developmental anomalies (Nakashima & Akamine, 2005).

Clinical practice's revitalization procedures, known as CF-REP, don't fully align with the modern tissue engineering concept of pulp regeneration. This procedure is a long-standing approach in medicine and dentistry (Lin et al., 2021). The current tissue engineering trio can be converted into resident stem cells, customized scaffolds, and endogenous growth factors for cell-free tissue engineering (Nakashima & Akamine, 2005).

Vessels in pulp tissue play a critical role in the supply of nutrition and oxygen, act as a conduit for the transport of metabolic waste, and regulate inflammation. Due to the unique anatomy of the tooth structure, the pulp, surrounded by a dense dentin, receives a limited blood supply from the apical foramen (Dissanayaka & Zhang, 2017). Nerve fibers contribute to the extravasation of immune cells to regulate inflammation, pulp homeostasis, angiogenesis, and pulp defense mechanisms. So, creating the right environment that helps with new blood vessel growth and nerve growth is important for regenerating dental pulp (Lambrichts et al., 2017). In this regard, nerve fibers contribute to pulp homeostasis, angiogenesis, and pulp defense mechanisms.

SB-REP is a method that relies on the use of biomaterials to create a structural foundation that supports cells in the process of tissue formation. SB-REP is versatile in that the strong mechanical properties of the scaffolds and the deconstruction process provide the time needed for the regeneration of tissues, as well as the inclusion of growth factors (Dissanayaka & Zhang, 2020). Growth factors and signaling molecules are polypeptide/protein structures that functionalize cells by binding to surface receptors of cells targeted for migration, adhesion, proliferation, and differentiation in stem cells (Lind, 1996; Schmalz et al., 2017). These molecules, which are also critical in the process of dental pulp regeneration, play a role in angiogenesis, neurogenesis, and dentinogenesis. In general, these molecules can be obtained in protein form from commercial preparations, endogenously derived from resident tissues and peripheral blood, or from transplanted cells. In REP, they can be sourced from leftover pulp or gum tissue, by using chelation on hidden dentin, from blood clots that come from the area around the tooth root, or by transplanting platelet concentrates (autologous biomimetic scaffolds) from peripheral blood into the root canal space (Schmalz et al., 2017).

These advances in REP allow the organization of hard and soft tissues developing in the root canal space to be more controllable and the nature of the regenerated tissues to be anticipated. However, a finite element analysis revealed that PDL and tooth structures formed with dentin and cement showed similar biomechanical performance under various scenarios, even when the newly formed tissues lacked odontoblast-like cells and were rich in reparative tissues such as cementum. The study emphasizes that teeth treated with regenerative endodontics may perform similarly to physiologically developed teeth with minimal differences in orthodontic processes, especially under balanced and low forces, but these should be confirmed under in vivo conditions (Bucchi et al., 2022).

Root resorption is one of the most common complications of orthodontic tooth movement in both endodontically treated and vital teeth. Regardless of the orthodontic treatment method or type of orthodontic appliance applied after REP, it has been observed that periapical remodeling occurs while the periapical infection resolves, and the teeth are asymptomatic during active and retentive orthodontic treatment periods (Chaniotis, 2018; Jawad et al., 2018; Natera & Mukherjee, 2018; Yoshpe et al., 2025).

When treating REP-treated teeth with orthodontics, it should be focused on the general treatment plan, orthodontic appliance selection and force parameters. If necessary, the option of partial or complete exclusion of REP-treated teeth from orthodontic forces should be considered, and light and short-acting forces should be applied. Furthermore, strict endodontic follow-up should be performed before, during, and after orthodontic treatment as long as root development continues (Jawad et al., 2018). When to apply orthodontic forces to teeth with REP depends on how long it has been since the tooth died, how symptoms have progressed after REP, the development phase of the tooth's root, and the orthodontic treatment plan selection (Bucchi et al., 2024). Therefore, cooperation and interaction between both disciplines is important and necessary to improve the management of the patient in need of REP requiring orthodontic treatment and the patient's compliance with the treatment process.

Conclusion

We should not ignore the fact that the forces applied during orthodontic treatment can cause inflammatory and vascular changes in the periodontal ligament and pulp. In particular, maintenance of pulp health and management of the inflammatory process are key factors that increase treatment success. Regenerative endodontic approaches support root development in immature teeth, and multidisciplinary clinical applications, where cases in the common age group are widely addressed, are promising. However, early and accurate planning of orthodontic and endodontic treatments is of great importance in preventing possible complications, maintaining the patient's long-term oral health, and increasing patient compliance with treatment. Therefore, continuous communication and collaboration between specialists will provide patients with the most appropriate and effective treatment approaches. In the future, the integration of pulpal tissue engineering and innovative approaches will lead to more successful and advanced treatment options in both orthodontics and endodontics.

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Chapter 5

Orthodontic-Pedodontic Multidisciplinary Treatments and Current Approaches

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Abstract

Primary teeth play a crucial role in preserving space for the proper eruption of permanent teeth. Premature loss of primary teeth can lead to the migration of adjacent teeth, resulting in crowding, occlusal malocclusion, and impaction of permanent teeth. Space maintainers are utilized to prevent these complications, In recent years, advancements in digital technologies, including CAD/CAM systems and 3D printing, have enabled the development of customized space maintainers with precision and faster production. Bad oral habits typically emerge during infancy and often resolve spontaneously over time. However, the prolonged persistence of certain habits can lead to structural alterations in the teeth and jaw. Early identification and intervention of these habits play a crucial role in preventing future orthodontic problems and promoting the maintenance of a healthy oral structure. Anterior crossbite is a type of malocclusion characterized by the positioning of the upper anterior teeth more lingually to the lower anterior teeth. This condition can lead to aesthetic concerns and negatively impact the psychosocial development of children. Early interventions help prevent the occurrence of more complex orthodontic issues in later years. This review discusses current treatment methods for a multidisciplinary approach, addressing both pedodontics and orthodontics.

1. Current Perspective on Space Maintainers in Pediatric Dentistry

Primary teeth play a crucial role in maintaining space until permanent teeth erupt into the oral cavity. This ensures that permanent teeth emerge in the correct position when primary teeth naturally exfoliate. If primary

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teeth are lost prematurely, adjacent teeth may drift into the resulting space, potentially leading to occlusal disturbances, crowding, or impaction of permanent teeth.[1,2] In such cases, it is necessary to maintain the space with a space maintainer.

Space maintainers are of critical importance in preserving the space created by prematurely lost primary teeth, ensuring the proper alignment and eruption of permanent teeth.[3] Additionally, they contribute to the proper development of the dental arch by preserving arch length. The factors influencing the selection of an appropriate space maintainer include the child's dental age, the location of the lost tooth, the eruption timing of the permanent tooth, the presence of opposing teeth, the child's oral hygiene habits and cooperation, congenital absence of the permanent tooth, the amount of bone covering the permanent tooth, the time elapsed since the extraction, and parental consent. If these factors are not considered, the existing problem may worsen, making proper planning essential for selecting an appropriate space maintainer.[4]

Space maintainers are classified under three main categories (Table 1).[5]

Table 1. Space maintainer types

Space Maintainer Types					
Based on Usage Conditions		Based on Functions		Based on the Forces Applied to the Teeth	
Fixed Space Maintainers	Removable Space Maintainers	Functional	Non-Functional	Active	Passive
Band and Loop					
Crown and Loop					
Distal Shoe					

Different materials can be used in the production of space maintainer appliances. Recently, with the integration of 3D printers and CAD/CAM technology into dentistry, significant advancements have been made in the fields of pediatric dentistry and orthodontics. Digitally fabricated space maintainers allow for more precise and highly customized designs to be created quickly.[6] Additionally, digital impressions help prevent the gag reflex.[7] The clinical applicability of digital space maintainers is quite good. In this regard, there are studies indicating that they demonstrate excellent stability.[6,7] Since the digital workflow reduces the time spent at the patient's chair and the number of appointments, it can be inferred that the fear in pediatric patients may be alleviated, and communication with patients may become easier.[8,9] Although studies have shown that traditional space maintainers have a higher survival rate compared to digital space maintainers, and that metal-based space maintainers produced with 3D printers have higher clinical success than resin-based space maintainers, it has been reported that patients prefer the digital workflow more than traditional space maintainers.[8,10] Polyetheretherketone (PEEK) polymer is preferred in the production of digital space maintainers due to its superior fit and stability compared to traditional materials.[11] Furthermore, it can be considered an important alternative for pediatric patients with metal allergies or those who are sensitive to metallic tastes.[8]

In conclusion, digital space maintainers in pediatric dentistry offer many advantages, such as precision, personalized design, time efficiency and enhanced patient experience. Clinical studies have demonstrated the applicability and stability of these methods; however, there is still a lack of sufficient research regarding long-term retention compared to traditional methods. Materials like PEEK polymer and advanced digital workflows can provide more effective and patient-friendly solutions in pediatric dentistry.

2. Approach to Bad Oral Habits in Pediatric Patients

An action that is performed automatically and repeatedly is referred to as a habit.[12] Many oral habits begin spontaneously in infancy and cease on their own. The mouth is the primary and permanent area where emotions are expressed in both children and adults. Additionally, the mouth, which has been reported as a source of relaxation for anxiety, can become a comforting action when stimulated by the tongue, finger, nail, or cigarette.[13] Oral habits are examined under two main categories.[12]

2.1. Acquired oral habits: These are learned behaviors that can be easily stopped and the child can replace them with other behaviors as they grow.

2.2. Compulsive oral habits: These are behaviors that are ingrained in the child and when emotional pressures become unbearable, the child may find a sense of security in these habits. Preventing the child from engaging in these habits may cause them to feel anxious and worried.

Bad oral habits can lead to malocclusions. As a result of bad oral habits performed for 4 to 6 hours, posterior crossbite, open bite, and an increase in facial height and overjet may occur.[14,15] The duration of the bad oral habit is more important than the force applied; the pressure from the lips, cheeks, and tongue are the most effective factors on tooth position.[14] If bad habits are discontinued by the age of 4, even if an anomaly occurs, it can spontaneously correct itself with the continued developmental process.[5] It is important to identify bad oral habits and determine the type of malocclusion they cause in clinical evaluations. Additionally, a comprehensive understanding of this issue is necessary to determine the appropriate treatment method.[5] Bad oral habits are repetitive behaviors that lead to the disruption of tooth structure in the oral cavity. The effects of the habit vary depending on the type of behavior, the age at which it begins, and its duration.[16] These habits include thumb sucking, pacifier use, lip sucking, teeth grinding, nail biting, bruxism, mouth breathing, and tongue thrusting.[17]

2.3. Thumb sucking: It is the most common oral habit, and it has been reported that its prevalence varies between 13% and 100% in some societies.[12] If a child develops this habit during the first year of life, parents should gently remove the finger and redirect the child's attention to other objects, such as toys. Some children who do not give up this habit may stop the behavior when their permanent teeth come in; however, there is also a tendency for the sucking habit to continue into adulthood. The bottle is often used by parents not only for feeding purposes but also to help the child fall asleep, calm down, and reduce crying. A child accustomed to this situation may develop the habit of thumb sucking in the absence of access to a bottle, in an attempt to fill the emptiness. Additionally, babies may develop the habit of thumb sucking for reasons such as gaining attention, expressing discomfort, relieving pain during the teething process, reducing the itching sensation, and satisfying their sucking reflex.[5] There are two types of thumb sucking: active and passive.[12] In the active type, a strong force is applied by the muscles during sucking, and if the habit continues for a long time, it can negatively affect the position of the permanent teeth and the shape of the mandible. In the passive type, the child places their finger in the mouth, but since no force is applied on the teeth and mandible, this habit is not associated with skeletal changes.[18,19] As a result of thumb sucking, anterior open bite, increased overjet, lingual inclination of lower incisors and labial inclination of upper incisors, posterior crossbite, abnormal swallowing and tongue thrusting, deep palate, speech disorders, and eczema or abnormal widening on the fingers may be observed. The severity of these outcomes can vary depending on the timing of thumb sucking in relation to the dentition stage and the angle at which the finger is held.[20] It has been reported that in children who have a sucking habit for 6 hours or more per day, especially during the night or sleep, serious anomalies in the dentoalveolar system and minor skeletal defects may develop.[18,21] Additionally, studies have reported a strong correlation between thumb sucking and temporomandibular joint

(TMJ) dysfunction during both the primary and permanent dentition periods.[22,23] For these reasons, it is important to discontinue the thumb sucking habit. In order to prevent the issues caused by such habits, they should be detected and eliminated at an early stage. Before resorting to appliance use, if the child is sufficiently mature, the negative effects of thumb sucking should be explained, the importance of breaking the habit should be emphasized, and the child should be supported in adapting to this process with a convincing approach.[24] Moreover, encouraging the child by instilling self-confidence and pride in this matter can also be an effective method for quitting thumb sucking.[24] If a child wants to quit the habit but is unable to do so, reminder strategies such as wrapping the finger with water-resistant adhesive tape, using a single-fingered glove or sock, and coating the finger with a bitter-tasting substance, especially during sleep times, can help in breaking the habit. Sometimes, this may be perceived by the child as a punishment; however, the child should be informed that these methods are not actually a form of punishment, but rather are intended to assist the child in overcoming the habit.[16] The treatment of thumb sucking can also be achieved through a reward system. A motivating reward can encourage the child to abandon the habit. If the child successfully gives up the habit within the designated time, their effort should be praised, and the habit can be permanently broken with the reward, thus increasing the child's trust in the process.[16] Despite these treatment methods, if the habit persists, an appliance therapy should be initiated. Extra-oral appliances are more effective than intra-oral appliances because they do not interfere with speech, are easier to prepare, and do not disrupt oral hygiene. The most commonly used appliance is the thumb appliance. The acrylic barrier in the thumb appliance prevents thumb sucking; however, it is important for the family to monitor the child to ensure they do not suck other fingers. To minimize the potential disadvantages of intraoral appliances, a new electronic reminder appliance has been developed for children with habits, designed with a modified thumb appliance. This innovative appliance functions as an effective reminder by triggering an alarm when the child brings their finger to their mouth, helping to break the habit. This system provides a more practical and successful solution for both the child and the parents during the treatment process.[16] It has been reported that *Thumbsie*, which is manufactured in the United Kingdom and made from fabric, features patterns that attract children's attention and is highly effective in breaking the habit.[25] In addition, elbow protection appliances can prevent thumb sucking. With the modified form of this appliance, *the Three-Alarm System*, not only is the thumb sucking physically blocked, but when the child attempts to engage in the habit, a chip system integrated into the appliance plays the child's favorite music. This serves as a behavioral reminder. Thus, the process of breaking the habit is supported in a fun way, while also increasing the child's psychological motivation to change their habits.[26] Both fixed and removable intraoral appliances can be used in the treatment of thumb sucking.[27] In the case of using fixed or removable appliances, parents should be informed about potential issues that may arise during speech or eating within the first 24-48 hours; these issues are usually normal and resolve on their own. After the active phase of treatment, the appliance should remain in the mouth for an additional 3 to 6 months to minimize the potential for relapse.[24] *Coffin spring, quad helix, palatal crib, expansion appliances,* and *the W ark appliance* also provide an effective treatment approach in preventing harmful oral habits. These appliances can be used to regulate dentoalveolar alignment and eliminate functional disorders, thereby offering a more comprehensive solution during the treatment process [28]. It has also been reported that *the modified Haas appliance* has yielded successful results in cases of crossbite and open bite resulting from thumb sucking.[29] *The quad helix appliance*, a fixed appliance with the ability to expand the maxillary arch, must be used for at least 6 months in total—3 months to correct the posterior crossbite caused by thumb sucking and an additional 3 months for stabilizing the movement.[16] In cases of open bite resulting from thumb sucking, *the palatal crib appliance* is another option.[30] The appliance, which is recommended for 12 months of use, can also be used for retention purposes after the treatment with *the quad helix appliance*.[16] In recent years, *position-trainer appliances* are increasingly used in the treatment of harmful habits. This appliance is especially preferred in cases of anterior open bite which is suitable for children in the mixed dentition stage, aged 6-10 years, It is advantageous when the patient is willing to undergo treatment but does not want to use a fixed appliance. Available in various sizes, *the position-trainer* eliminates the need for impressions and the custom fabrication process, making the treatment process faster and more practical. The appliance, which is recommended for use between 6-12 months, should be worn for at least one hour during the day and throughout the night.[31] *The Bluegrass appliance*, known as the habit correction cylinder, is another appliance used in the treatment of thumb sucking. An important advantage of this appliance is the use of a cylinder instead of the traditional crib. Its more compact design prevents it from being noticed from outside the mouth. Additionally, the cylinder functions as a neuromuscular stimulator on the tongue, offering a significant feature that can assist patients, particularly during speech therapy. Thus, the appliance is used not only as a habit-correcting tool but also as a treatment device that provides functional improvement.[32] The modified form of the appliance is tailored to individual needs and functions not only as a correction tool for thumb sucking and tongue thrusting habits but also as an aesthetic space maintainer.[33]

2.4. Pacifier use: Pacifier use is common in most countries and does not cause permanent changes in the dentition if discontinued by the age of 2-3 years. However, prolonged use beyond the age of 3 has detrimental effects on dental development, and continued use after the age of 5 further exacerbates these effects.[34] Prolonged pacifier use can lead to an overjet greater than 4 mm, Class II canine relationship, distal step occlusion in primary molars, anterior open bite, and crossbite in later stages.[35] Pediatric dentists frequently emphasize that pacifier use may be less harmful compared to thumb sucking habits, as it generally decreases between the ages of 2 and 4. Therefore, pacifier use may be recommended for infants exhibiting non-nutritive sucking behavior.[36] Studies have shown that even when used for more than two years, orthodontic pacifiers do not significantly contribute to the development of harmful oral habits or malocclusions. Additionally, it has been reported that children who begin using orthodontic pacifiers early, within the first three months, have a lower likelihood of developing a thumb-sucking habit.[37]

2.5. Lip sucking and biting: This issue is observed predominantly in the lower lip in nearly all cases and can lead to the labial inclination of the upper incisors and the lingual inclination of the lower incisors.[38] Furthermore, the lower lip may become trapped between the upper and lower anterior teeth, resulting in dental misalignment. This habit is associated with lip dryness and inflammation and has been reported to cause vermilion hypertrophy in severe cases.[39] Moreover, in some individuals, it may lead to chronic herpes formation or lip fissures.[12] In severe cases of lip sucking, periodontal health may be adversely affected, leading to gingival recession and increased tooth mobility.[40] It has been reported that the use of a *lip bumper appliance* in treatment can help reduce mentalis muscle hyperactivity and labiomental tension, facilitate an increase in arch length, improve incisor inclination, and decrease excessive overjet.[41]

2.6. Nail biting (onychophagy): Typically emerging after the ages of 3–4 and peaking around the age of 10, nail-biting behavior is frequently observed during adolescence but tends to decline in later years.[12] The prevalence of nail biting in adolescence is higher among males compared to females, while no significant gender differences are observed in children under the age of 10.[42] In individuals with chronic nail-biting habits, particularly during orthodontic treatment, an increased incidence of *Enterobacteriaceae* in the oral cavity has been identified.[43] Nail biting is associated with various psychosocial issues, which can indirectly affect orthodontic outcomes. Children who engage in this habit may experience anxiety or stress, potentially compromising their cooperation during orthodontic treatment.[44] Additionally, localized oral health problems, such as gingivitis, have been reported in children with nail-biting habits.[45] If the habit persists, it may lead to dental issues such as rotation, labial or lingual inclination, crowding, and diastema, all of which contribute to malocclusion.[46] Treatment approaches include psychological counseling and communication-based interventions, as well as the use of electronic reminder devices to gradually eliminate the habit.[47] The application of bitter-tasting nail polish has also been shown to assist in deterring children from the habit.[48] Furthermore, cognitive-behavioral therapy (CBT) can be employed to provide psychological support for affected individuals [48]. In severe cases, particularly in patients with obsessive-compulsive disorder (OCD), treatment may involve the administration of selective serotonin reuptake inhibitors (SSRIs) to alleviate anxiety.[49] Furthermore, customized fixed appliances designed to be placed in the mandibular arch, specifically in the canine-to-canine region, have been successfully utilized in young adult patients for the management of nail-biting habits.[50]

2.7. Mouth breathing: Mouth breathing can result from various causes, including allergic rhinitis, hypertrophic adenoids and tonsils, nasal septal deviation and obstructive sleep apnea.[51] Children who exibit mouth breathing are more prone to Class II malocclusion, anterior open bite, and crossbite. These conditions stem from abnormal growth patterns influenced by mouth breathing.[52] Mouth breathing disrupts facial development, leading to long, narrow faces, high palatal vaults, and a constricted oral cavity, ultimately resulting in aesthetically undesirable facial features.[53] In addition, mouth breathing has been associated with an increased risk of periodontal problems, such as chronic gingivitis, periodontitis, halitosis and has also been reported to contribute to a higher incidence of dental caries.[54] The airway obstruction caused by mouth breathing can interfere with sleep patterns, leading to fatigue and potential academic difficulties, which are often misdiagnosed as attention deficit disorder.[53] Beyond its dental and academic effects, mouth breathing is linked to lower oxygen saturation levels and a higher prevalence of allergic diseases, posing negative impacts on a child's overall health and development.[52] Treatment typically requires a multidisciplinary approach addressing the underlying causes of mouth breathing. For instance, collaboration between orthodontists and otolaryngologists may be necessary to manage conditions such as obstructive sleep apnea and malocclusion.[55] In cases where mouth breathing is associated with ankyloglossia, timely frenectomy combined with myofunctional therapy can be an effective intervention.[56] Treatment options for children experiencing halitosis include antimicrobial photodynamic therapy, and the potential efficacy of probiotics is currently being investigated.[57] If mouth breathing impairs sagittal maxillary development, rapid maxillary expansion (RME) appliances can be used to widen the maxilla, thereby improving nasal ventilation and reducing mouth breathing. RME has been reported to enhance nasal dimensions and improve nasal respiratory function in the short term.[58] In cases of unilateral crossbite associated with mouth breathing, *the quad-helix appliance* may serve as an effective orthodontic intervention.[5] Moreover, targeted exercises can promote nasal breathing and improve overall respiratory function.[59]

2.8. Tongue thrust: Tongue thrust is an orofacial myofunctional disorder characterized by an abnormal resting tongue posture and an altered tongue position during swallowing. It is commonly referred to as "atypical swallowing" and is also associated with terms such as "deviant swallowing" or "infantile swallowing".[60] Tongue thrust can contribute to malocclusions, while preexisting malocclusions may also exacerbate it.[61] This habit, particularly when the infantile swallowing pattern persists into later childhood, significantly contributes to anterior open bite and maxillary incisor protrusion.[62] Chronic tongue thrust may lead to dentoalveolar complications, such as atypical root resorption in primary anterior teeth, which can result in their premature loss.[33] A combined approach of orthodontic treatment and myofunctional therapy is emphasized in the management of tongue thrust. Appliances such as the *Hybrid Habit Correction Appliance* can be utilized to address tongue thrusting and other oral habits, particularly in patients who do not comply with traditional treatment methods.[63] Since this appliance is fixed, it helps improve patient cooperation and can be integrated with fixed orthodontic appliances, providing a comprehensive treatment approach. Another appliance, *the Tongue Right Positioner (TRP)*, is employed in orthodontic treatment to correct atypical swallowing and improve oral functions. TRP is designed to promote proper tongue positioning and function, thereby stabilizing the treatment of dental malocclusions and addressing respiratory disorders such as sleep apnea.[64] This appliance facilitates a faster establishment of a correct swallowing pattern compared to exercises, Unlike conventional methods, TRP provides a passive approach to habit correction, as opposed to active participation required in exercises.[65] Additionally, it contributes to upper airway anatomy by reducing the height of the oral floor and expanding the pharyngeal area.[64]

2.9. Bruxizm: Bruxism is characterized by the involuntary grinding or clenching of teeth, which can occur either during sleep (sleep bruxism) or while awake (awake bruxism).[66] Bruxism is a multifactorial condition influenced by genetic, psychological, physiological, and lifestyle factors, with significant contributors including stress, anxiety, sleep disorders, and behavioral abnormalities.[67] Unless it is treated, it can lead to pathological tooth wear, hypersensitivity, and even tooth loss. Additionally, bruxism has been associated with headaches, myalgia, and temporomandibular joint disorders.[67] Bruxism can disrupt sleep patterns and negatively impact overall health and well-being, making daily activities and social relationships more challenging. It is increasingly recognized as a significant issue among children and adolescents, with an observed rise in cases linked to modern stressors and lifestyle changes.[67] The diagnosis of bruxism can be made using both instrumental and non-instrumental methods. Non-instrumental methods include self-reports, questionnaires, and medical history, while instrumental methods involve polysomnography and electromyography to measure muscle activity.[68,69] Unlike children, adult patients with long-term bruxism often exhibit mandibular angle changes and bone apposition, which can be identified through orthopantomographic radiographs.[70] In terms of treatment, the first-line approach typically involves encouraging patients to maintain good sleep hygiene and perform muscle relaxation exercises. As they help prevent dental attrition and reduce teeth grinding, occlusal splints are the most commonly used among intraoral appliances.[71] Certain medications, such as clonazepam, may improve sleep bruxism in patients with psychiatric comorbidities; however, due to insufficient research, their widespread use is not recommended.[71] Other drugs, including hydroxyzine, trazodone, and flurazepam, have been reported to reduce bruxism based on self-reported data and may alleviate associated headaches.[72] While psychotherapy, conventional medical treatments, and surgical interventions are also potential treatment options, no single gold-standard therapy has been specifically recommended for bruxism.

In conclusion, regarding the impact of stress on the development of oral habits, the increasing stress levels in modern society have led to these habits becoming more common compared to previous decades. Since oral habits negatively affect the dentoalveolar system, more attention should be given to controlling and preventing them.[12]

2.10. Dental Anterior Crossbite in Children

Anterior crossbite is a type of malocclusion where the upper front teeth are positioned more lingually than the lower front teeth due to various dental or skeletal incompatibilities. It is seen in approximately

4-5% of children in the primary dentition phase. This malocclusion can lead to significant aesthetic concerns, as well as negatively affecting the quality of life related to oral health in children, causing dissatisfaction with appearance and potential psychosocial issues. Early diagnosis and treatment are crucial to prevent complications that may arise during the mixed and permanent dentition phases. Otherwise, periodontal damage, enamel wear, tooth mobility, temporomandibular joint disorders, and developmental abnormalities affecting skeletal structures may occur. Pediatric dentists routinely manage the treatment of dental anterior crossbite in clinical practice. Interventions may include appliances or restorative treatments, with these methods showing successful results in correcting the anterior crossbite within weeks.[73,74] Moreover, in Class III malocclusion cases with anterior crossbite, early intervention significantly improves facial profile and dental relationships, supporting healthier growth patterns.[75]

3.1. Treatment with removable appliances: Removable appliances are an effective method for correcting anterior crossbite, especially in children during the mixed dentition phase. These appliances typically include labiolingual springs, anterior inclined planes, or screws. The advantage of removable appliances is that they allow the patient to easily maintain oral hygiene and provide comfort during the treatment process. However, as the appliance can be taken in and out, the success of the treatment largely depends on the patient's regular and proper use of the appliance. In cases where there is insufficient space for the tooth to move from the back to the front, space must be created before the teeth in the crossbite can be proclinized. For this purpose, expansion in the midline can be achieved using a screw, or neighboring teeth that alter the position of the affected tooth can be directed to their proper positions using mesiodistal or labiolingual springs to create space.[5] *The finger-spring appliance* is another alternative for treatment. Due to its short treatment time and less invasive nature compared to fixed appliances, patient compliance and comfort are generally sufficient.[76] Labiolingual springs included in removable appliances should be activated by 1-2 mm each month. If the movement of multiple teeth in the anterior direction is desired, an anterior screw appliance or a three-way screw appliance (Y-type appliance) can be preferred. In these appliances, activations are performed in 2 turns per week (1 turn = 0.25 mm). One of the most important factors to consider in all removable appliances is ensuring sufficient space in the front with posterior bite planes. This aims to prevent trauma to the teeth in the crossbite and improve the effectiveness of the treatment process.[5]

3.2. Treatment with fixed appliances: *The Catlan appliance*, also known as the lower inclined bite plane, is a fixed orthodontic appliance used to correct anterior crossbite, where the upper anterior teeth are positioned behind the lower anterior teeth. The appliance creates a slight lingual movement in the lower teeth while generating labial movement in the upper teeth.[77] The appropriate age range for use is between 8 and 11 years old. One study showed that the appliance was effective in correcting anterior crossbite in a short period, approximately three weeks, without causing damage to the teeth or surrounding periodontal tissues.[77] Another case series compared *the Catlan appliance* with other orthodontic appliances and found that it provided the shortest treatment duration but was less comfortable than alternatives.[76] *The 2x4 appliance* is effective not only in the treatment of crossbites but also in early-stage anterior malocclusions such as anterior crowding and midline diastemas, particularly for malpositioned permanent upper incisors.[78] This appliance is successfully used to correct single-tooth anterior crossbites, provides extensive control over the anterior teeth and allows for precise movements. The appliance is part of a preventive and interceptive orthodontic treatment approach that aims to simplify or eliminate the need for more complex treatments in the future. Early intervention can prevent more complications associated with untreated malocclusions. The appliance is well-accepted by patients, requires fewer adjustments, and contributes to faster treatment outcomes, making it a preferred choice among orthodontists.[79]

3.3. Treatment with restorative techniques: It is a treatment type applied with aesthetic pediatric zircon or strip crowns. Crossbite can be successfully treated within 1 to 2 weeks using the recommended technique. A 6-month follow-up showed that the occlusion stabilized into a normal sagittal relationship, allowing normal dentofacial growth and development to continue.[74] The technique presented here is a method that pediatric dentists can add to their treatment options for correcting anterior crossbite diagnosed during the primary dentition stage.

Conclusion

The collaboration between orthodontics and pediatric dentistry plays a crucial role in maintaining children's oral health and monitoring dental development. Accurate diagnosis, appropriate treatment methods, and regular monitoring processes carried out in the early stages are fundamental factors in ensuring long-term healthy oral structure and proper alignment of teeth. The integration of these two disciplines not only enhances the effectiveness of treatment processes but also contributes to fostering an informed attitude toward children's dental health. Strong cooperation between orthodontics and pediatric dentistry is a critical step in ensuring that children have a healthy and aesthetically pleasing smile for a lifetime.

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Chapter 6

Orthodontics and Periodontology: Multidisciplinary Treatment and Current Approaches

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Abstract

Orthodontics provides ideal tooth and jaw relations and has important biological effects on the periodontium. Periodontal health should be constantly considered throughout the orthodontic treatment process because changes in the periodontium also directly affect the success of orthodontic treatment.

This chapter will evaluate the effects of orthodontic treatment, different orthodontic movements, and mechanics on periodontal health and will be discussed separately. Also, the methods used to prevent relapse that may occur after orthodontic treatment and their effects on periodontal health will be discussed.

The common result of the studies indicates that orthodontic treatment planning in individuals with periodontal disease should be done carefully and by considering the systemic health of the patient. The success of orthodontic treatment is significantly increased if the above-mentioned points are taken into consideration.

Consequently, a multidisciplinary working environment should be established to reduce the negative effects of orthodontic treatment on the periodontium and to increase the success of treatment.

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Introduction

Microbiology studies pathological microorganisms, being one of the most important factors affecting human health since the beginning of life. While oral flora is home to a large number and variety of harmful and harmless microorganisms, oral microbiology examines harmful microorganisms in the oral environment.

Van Leeuwenhoek examined microorganisms in dental plaque using a simple microscope in the 17th century. This event is considered the beginning of oral microbiology (He & Shi, 2009). Robert Hooke, a contemporary of the same period, further improved this primitive microscope to make microorganisms more visible (Gest, 2005). Although the invention of the microscope goes back to the 17th century, an Indian community leader named 'Vardhmana Mahavira,' who lived in the period before Christ, suggested the existence of small microorganisms named 'Nigora' (Singh, 2009). Along with the invention of the microscope, there has been a rapid increase in the level of knowledge of humanity; the existence of microorganisms, the reality of which was controversial, has been proven, and the microbiology department has been established.

Oral microbiology has developed considerably in light of this cumulative knowledge and technological developments and has become an important branch of science that helps dentistry in the understanding, classification, and treatment of periodontal and systemic diseases (İşler, 2023).

It is believed that periodontal diseases have existed since the beginning of human history. Especially paleopathologists examining skulls from ancient times point to destructive periodontal diseases. A Sumerian tablet from 5000 BC explains that the Sumerian people suffered from periodontal diseases and applied herbal mixtures to the gums and massaged them for treatment (Brkić & Pavlić, 2017).

Hesy-Re, who lived in the 3rd Egyptian Dynasty in the 27th century BC, is the oldest person identified as a dentist (Brkić & Pavlić, 2017). A tablet in his tomb bears the phrase "the greatest of those who deal with teeth and the greatest of physicians". He is also known as the first person to define periodontal disease (Mitsis & Taramidis, 1995; Ziskind & Halioua, 2007).

During the Renaissance period, Italian anatomist and physician Bartolomeo Eustachi (1514-1574) described the periodontal ligament, deciduous and permanent teeth in his work 'Libellus de Dentibus' (Gold, 1985). He associated the reason for the increased tooth mobility in old age with the expansion of this periodontal ligament between the root surface of the tooth and the underlying bone. He also recommended the removal of calculus and granulation tissue to tighten this loose junction (Dentino et al., 2013)

Pierre Fauchard (1678-1761), considered the father of dentistry, included some periodontal issues in his book 'Le Chirurgien Dentiste' (Maloney & Maloney, 2009). He introduced periodontal instruments of his own invention, such as a donkey's nose, a parrot's beak, and a Z-shaped hook, and described the methods of scaling using these instruments. He also proposed the method of fixing the moving tooth using gold wire (Maloney & Maloney, 2009).

In the 19th century, two German physicists, Robert Ficinus (1809-1852) and Adolph Witzel (1847-1906), attributed the bone loss in the alveolar bone with periodontal disease to the presence of bacteria. The development of microbiology at that time played a major role in this (Dentino et al., 2013; Newman et al., 2020).

1. What is Periodontology?

The structure that supports the tooth and connects to it with various components is called periodontium (Ten Cate, 1997). The department that analyzes the healthy and diseased conditions of these periodontal tissues (periodontal ligament, gingiva, alveolar bone, cementum) is called periodontology (Dentino et al., 2013) (Figure 1).

Periodontal disease is defined as a disease state that occurs when the integrity of this periodontal tissue is disrupted and is characterized by various clinical signs and symptoms (Baelum & Lopez, 2003; Tonetti & Mombelli, 1999; Van Der Velden, 2005).

John M. Riggs (1810-1885), known as the father of periodontology in the USA, believed that all stages of periodontal diseases were caused by calculus. Riggs achieved a success rate of over 90% by cleaning and curettage of calculus and providing oral hygiene education to his patients (Merritt, 1921).

Willoughby D. Miller (1853-1907) is known for his groundbreaking ideas on the aetiology of dental caries, such as the 'non-specific plaque hypothesis.' He also proposed the role of bacteria in alveolar pyorrhea and the potential of normal oral bacteria to cause periodontal disease (Theilade, 1986).

In the 20th century, alveolar pyorrhea was recognized as a treatable disease, and thus 'Periodontology' became a separate branch of dentistry (Dentino et al., 2013).

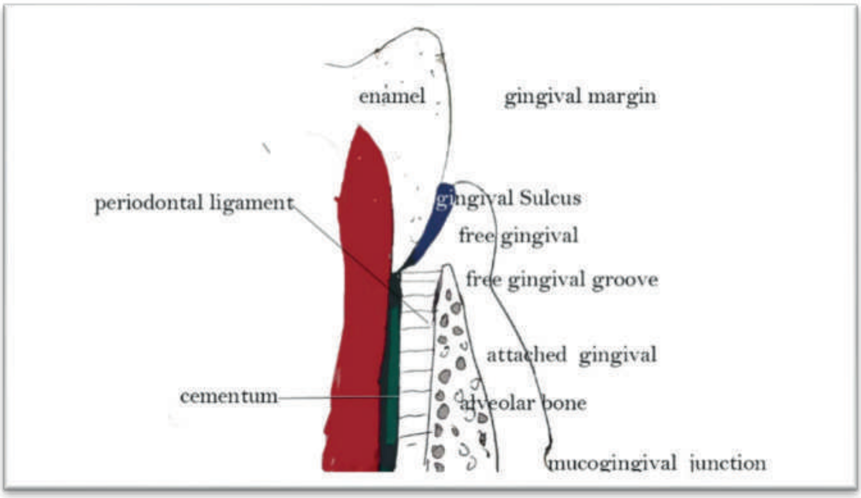

Figure 1: Anatomy of the periodontium (Madukwe, 2014).

Dental plaque is a biofilm layer formed by the settlement of a large number of microorganisms on the tooth surface in the oral cavity. It is among the main factors responsible for the formation of dental caries and periodontal disorders (Rosan & Lamont, 2000).

Dental plaque (biofilm), which is attached to tooth surfaces by means of an exopolysaccharide layer and for which streptococci are mainly responsible for its formation, is among the main causes of caries and dental diseases (Türkmen et al., 2016). Dental plaque is formed by pellicle formation, initial adhesion, maturation, and disintegration stages (Huang et al., 2011) (Figure 2).

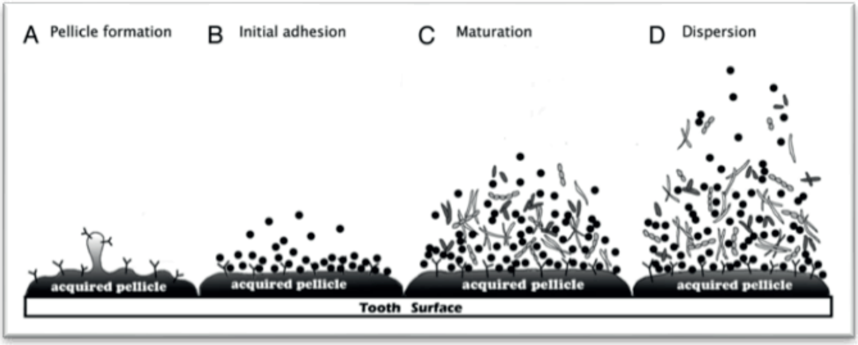

Figure 2: Stages of dental plaque formation (A, Pellicle formation. B, Initial adhesion. C, Maturation. D, Dispersion Stages of dental plaque formation)(Huang et al., 2011).

The most common form of periodontal disease caused by this structure called dental plaque is gingivitis. Bleeding that occurs when the gingival groove is probed slightly is one of the most important symptoms of gingivitis. Apart from this, swelling, redness, and an increase in gingival groove fluid are among the other symptoms (Mariotti, 1999).

Periodontology has become a separate branch of dentistry that has evolved with the cumulative accumulation of knowledge in the light of this information throughout history, protecting the health of the periodontium surrounding the teeth and playing an important role in the treatment of diseases.

2. The Interrelation Between Orthodontics and Periodontology

Today, the expectation from orthodontic treatment is not only limited to providing aesthetic improvement. It also aims to maintain a healthy periodontium and to eliminate orthodontic anomalies by creating a standardized tooth alignment. Achieving this goal is only possible by working in close cooperation with periodontology (Uludağ & Şar, 2014).

Ideal occlusion prevents food accumulation between the teeth and makes oral hygiene easier to achieve. This is achieved in the presence of adequate overjet and overbite with properly positioned and sized dental arches and incisal guidance of the anterior teeth. This ideal and uncrowded arch position has been found to be very favorable for oral hygiene (Kessler, 1976).

For orthodontic treatment to be successful, periodontal tissues should be under control before, during, and after treatment (Uludağ & Şar, 2014). This approach prevents the tooth movements that occur with orthodontic treatment from causing problems in periodontal tissues.

It is known that dental plaque formation increases significantly in patients under orthodontic treatment. This may cause undesirable changes in the periodontium and periodontal diseases in patients (Vinod et al., 2012). The bracket systems and/or orthodontic materials used may lead to more food accumulation and increased dental plaque formation.

While the need for periodontal treatment does not arise only in patients undergoing orthodontic treatment, the joint work of orthodontics and periodontology is required in the treatment of patients with periodontal disease. (Vinod et al., 2012). Periodontal problems that may complicate orthodontic treatment can be identified in advance, or periodontal problems that can be prevented with orthodontic treatment can be prevented with the multidisciplinary work of these two fields (Palomo et al., 2008).

Periodontal treatments other than major surgical operations such as pocket elimination should be performed before orthodontic treatment. Inflammation should be minimized as much as possible. This is because this inflammation can develop and progress much faster when combined with occlusal trauma and orthodontic movement than it can occur only in the case of chronic periodontal inflammation (Kessler, 1976).

3. Effects of Orthodontic Treatment on Periodontium

It is possible to obtain orthodontic tooth movement by applying controlled force with different types of orthodontic appliances (such as tipping, intrusion, extrusion, retraction, torque, and rotation). Resorption occurs on the side where the tooth applies pressure while moving, and apposition occurs in the opposite direction, that is, in the part where it causes stress. The simplest orthodontic movement is the tilting movement that occurs when the force is applied to one point of the tooth. The force applied to the crown causes it to rotate around the resistance center, which is approximately halfway to the root of the tooth (Proffit et al., 2020; Uludağ & Şar, 2014) (Figure 3).

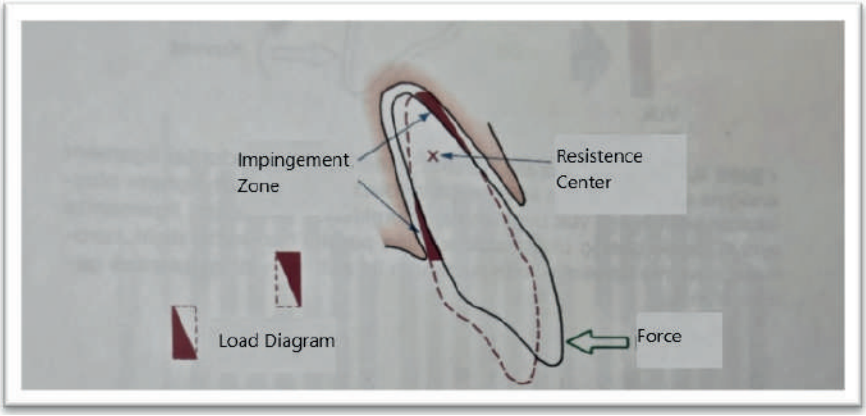

Figure 3: Impingement and stress zones in the alveolar bone due to orthodontic force (Proffit et al., 2020).

If the tilting movement occurs at the root of the tooth, it is called torque movement. If excessive torque force is applied to the orthodontic wire, resorptions and parallel fenestrations may occur on the buccal surface of the bone (Proffit et al., 2020; Uludağ & Şar, 2014) (Figure 4).

Figure 4: Mandibular anterior teeth with the apex overbuccalized to a large extent due to excessive and poor orthodontic forces (Proffit et al., 2020).

Intrinsic movement is the movement that occurs due to the expansion of the forces on the bone surface on a parallel line (Roberts et al., 1982). In order for a tooth to be able to move, the force diagram created from the periodontal ligament to the apex must pass through the resistance center of the tooth. It is required to apply approximately 2 times the force of the tilting movement to achieve this movement (Proffit et al., 2020) (Figure 5).

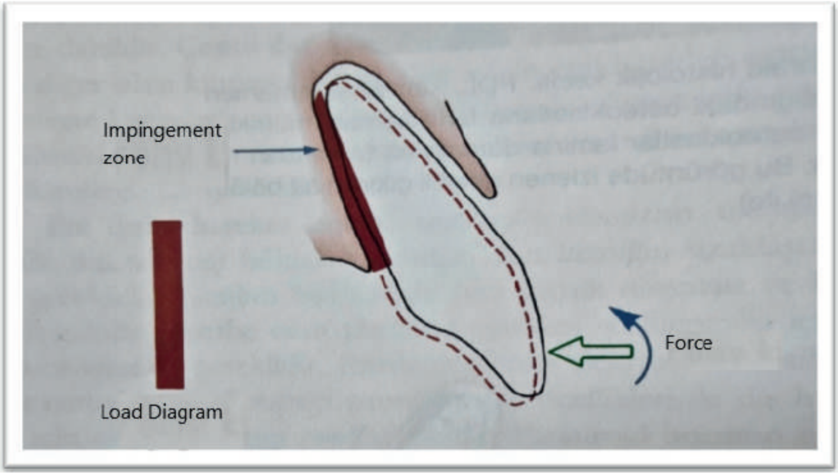

Figure 5: The impingement zone and force diagram formed in the reciprocating motion (Proffit et al., 2020).

Movement towards the pockets formed in the bone can provide improvement in the periodontium (Polson et al., 1984).

Rotation is one of the most difficult movements in orthodontics. The possibility of relapse is extremely high because during this movement, the previously mentioned zones of pressure and stress occur simultaneously on two different surfaces of the tooth. This can also cause fibrosis in the zones of bone apposition, especially in the marginal zone. This phenomenon may vary according to the different forces applied on different teeth (Uludağ & Şar, 2014).

The roots of malposed or rotated teeth may sometimes be very close to each other. This causes the presence of a thin interproximal septum in the parts where the roots are close to each other. Thus, periodontal tissues may be rapidly destroyed (Klassman & Zucker, 1969). Occasionally, the apex or part of the root of these rotated teeth may remain outside the bone. In such cases, bone defects called fenestration and dehiscence may occur, as seen in incorrectly applied torque movement. Correction of these rotated teeth and placing them into the alveolar bone in such cases can correct bone defects such as fenestration and dehiscence (Kessler, 1976).

Extrusion is an orthodontic movement that shapes the tooth, alveolar bone and surrounding soft tissues when it is performed within the framework of ideal forces, while only creating a stress zone in the periodontal ligament (Uludağ & Şar, 2014). Since it also shapes the surrounding tissues, it can be used to eliminate the pocket depth of intraosseous defects (van Venrooy & Yukna, 1985). These positive effects of extrusion are maintained even if the tooth is later re-intruded (Kessler, 1976).

Among these orthodontic movements, the one that has the potential to cause the most periodontal problems is the intrusion movement due to the potential accumulation of forces at the root tip (Uludağ & Şar, 2014) (Figure 6).

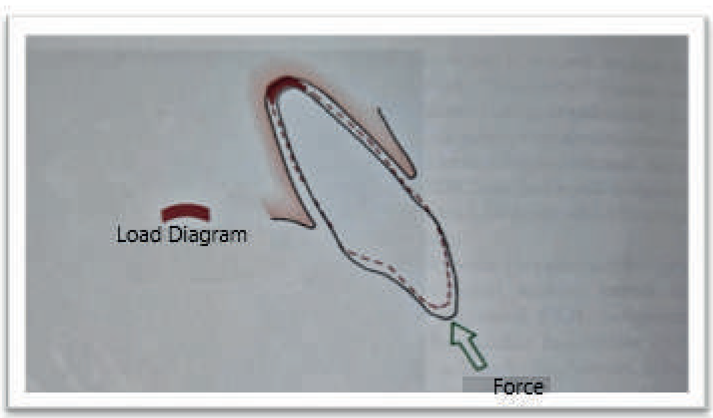

Figure 6: When a tooth is intruded, the force is concentrated on a single point apically, making it a potentially destructive movement (Proffit et al., 2020).

Intrusion of malposed maxillary centers does not always disrupt the relation of the gingival attachment to the tooth. However, if we bring the central teeth closer to the bone, we can turn suprabony pockets into infrabony pockets. This may require a surgical procedure in the future. Nevertheless, in order for this lesion, which turns into an infrabony pocket, to become inflammatory, inflammatory factors must occur again (Kessler, 1976).

4. Effects of treatment mechanics on the periodontium

Most patients with good oral hygiene develop gingivitis following orthodontic appliances, but attachment loss is rare. According to some studies (ZACHRISSON & ALNÆS, 1974; ZACHRISSON & ALNAES, 1973), attachment loss has also been observed following fixed orthodontic appliances. Intraoral elements of fixed orthodontic treatment (such as brackets and band-fixed appliances) cause an increase in the rate of plaque formation (van Gastel et al., 2007).

Most researchers who have conducted systemic analyses of the effects of fixed appliances on the periodontium have found that fixed appliances cause a moderate change in periodontal status. No article reported a high level of associated change. It is generally accepted that gingivitis and plaque accumulation occur following orthodontic appliance placement (Cerroni et al., 2018).

Some researchers (Wu et al., 2020) conducted a meta-analysis study to compare the effects of fixed and removable orthodontic appliances on periodontal health. In this study, Plaque Index (PI), Gingival Index (GI), and Sulcus Probing Depth (SPD) values were analyzed, and it was concluded that the harmful effect of removable orthodontic appliances on periodontium was less compared to fixed orthodontic appliances. Removable orthodontic appliances are more advantageous in terms of oral hygiene and periodontal health because they can be removed and cleaned at any time.

The long-term effects of orthodontic treatment on periodontal health are contradictory (Cerroni et al., 2018). Some research results (Glans et al., 2003) revealed an improvement in periodontal health after orthodontic treatment, while others (Condò et al., 2013) showed an increased risk of mild to moderate periodontal disease.

5. Periodontal Changes and Relapse Prevention after Orthodontic Treatment

A certain amount of relapse is always seen in orthodontically treated rotated teeth. It has been stated that the biggest factor of relapse is the tendency of the stress in the transseptal and supracrestal fibers to release after treatment. Cutting the stretched fibers, i.e., 'Fiberotomy', is a technique that has been suggested to prevent relapse, and its success has been demonstrated by case studies (Ahrens et al., 1981).

More difficult than achieving the ideal occlusion is retention. Retention is an important part of orthodontics and its aim is to prevent relapse. Retention should be planned during the diagnostic phase of orthodontic treatment (Kharbanda, 2019). If necessary, overcorrection should be performed to increase the probability of success of retention.

In cases such as cleft lip and palate, treatment of excessive numbers of rotations and diastema closure, the susceptibility to relapse is higher, and fixed retention is necessary (Gill & Naini, 2012).

Fixed lingual retainers (Figure 7) are one of the most commonly used methods today, especially for the retention of mandibular anterior teeth. They provide longer and more reliable retention than traditional removable retainers because they are fixed and less disturbing to the patient (Üstdal et al., 2019).

Figure 7: Fixed lingual reinforcement appliance (Proffit et al., 2020).

The conclusions from a study (Quinzi et al., 2023) suggest that although removable retainers (Figure 8) are more advantageous in terms of periodontal health because they are easier to clean, their effectiveness varies from patient to patient because they require patient cooperation. The effect of fixed retainers on periodontal health was not statistically significant. For this reason, the physician should decide on the choice of retainer individually.

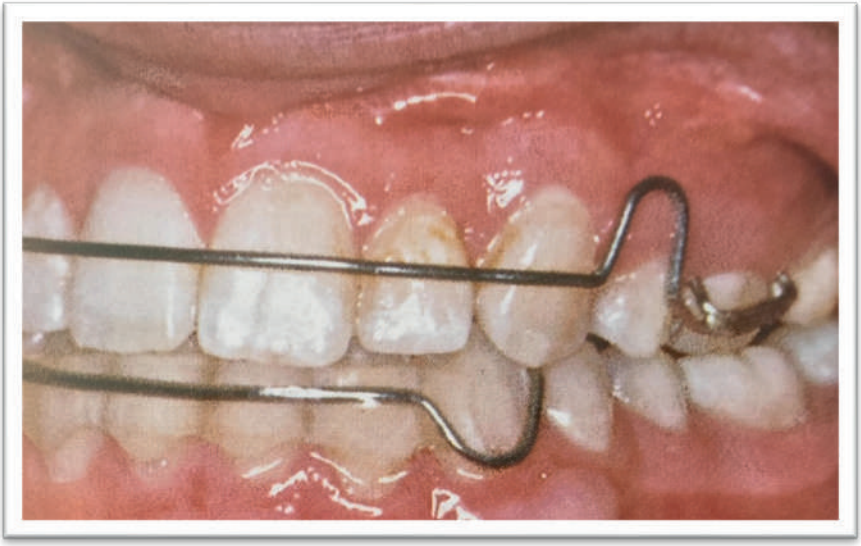

Figure 8: Movable reinforcement appliance (Proffit et al., 2020).

6. Orthodontic Treatment Approaches in Individuals with Periodontal Disease

If the patient's oral environment is healthy, the loss of attachments already present in the periodontium is not a contraindication for orthodontic treatment (van Gastel et al., 2007).

The effects of orthodontic treatment on the periosteum were analysed in detail in a study on patients with advanced periodontal problems. In these patients, elimination of deep periodontal pockets was not performed before starting orthodontic treatment, only phase-1 treatment was applied and oral hygiene training was given to the patient and phase-4 (maintenance phase) was started. The patient's gingiva, gingival pocket and alveolar bone were evaluated before phase-1 treatment, before and after orthodontic treatment and the values obtained were compared. It has been reported that existing advanced periodontal diseases do not progress if force is used within physiological limits and oral hygiene is maintained (Eliasson et al., 1982).

7. Multidisciplinary Solution of Aesthetic Problems

Some criteria should be considered for the control of gingival margin irregularities in the maxillary canine-canine region. If this irregularity is not visible and does not disturb the patient, it should be postponed until after orthodontic treatment. However, if it is in the visible zone and is severe enough to disturb the patient, the clinical crown length can be extended by performing procedures such as gingivectomy and extrusion in the discrepant zone (Kokich, 1996).

The most common cause of interdental papillary loss is contact deficiencies. Radiography techniques are used to determine the treatment of this problem. If the root tips of the 2 anterior teeth are diverging from each other in the radiographs, the root angles are corrected orthodontically. If it is evident from the radiographs that there is no problem, then the problem is usually due to the triangular form of the tooth, and in this case the treatment is either interproximal striping or composite restorations (Kurth & Kokich, 2001).

Gummy smile appearance occurs mostly in middle-school-high school-age individuals due to the thick or fibroid structure of the gingival phenotype in cases where the migration of the gingival ridge to the apical is retarded. If the aesthetic problem is severe, the treatment is surgical (Konikoff et al., 2007; Theytaz & Kiliaridis, 2008). The treatment of gummy smile seen in patients with deep bite, such as Class 2 Division 2, is the intrusion of the incisor teeth (Lapatki et al., 2002).

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Chapter 7

Orthodontics and Oral, Dental, and Maxillofacial Surgery: Multidisciplinary Treatment and Current Approaches

Ali Kağan Özen[1]

Abstract

This book chapter comprehensively addresses multidisciplinary treatment approaches between orthodontics and oral, dental, and maxillofacial surgery. In individuals with cleft lip and palate, orthodontic treatment before, during, and after the surgical process constitutes one of the cornerstones of treatment success when correcting skeletal jaw anomalies surgically. Additionally, the integration of impacted teeth into the oral cavity is only possible through coordinated planning of surgical exposure and orthodontic traction. In cases of severe maxillofacial deficiencies, gradual expansion of the jawbones is achieved through distraction osteogenesis; in this process, orthodontic treatment plays a critical role in ensuring harmony at both skeletal and dental levels. When these approaches are combined with individualized planning, interdisciplinary collaboration, and accurate timing, it becomes possible to achieve both functional and aesthetic success.

Orthodontics is essentially a branch of science that aims to ensure the hard and soft tissues in the jaw and facial region remain within normal growth and developmental limits. To achieve this goal, collaboration with both medical and dental specialties is often necessary. At the forefront of these specialties is oral and maxillofacial surgery. The main objectives of this collaboration include expanding the physical limits of orthodontic treatment, accelerating treatment, facilitating trauma rehabilitation, preventing or reducing orthodontic relapse, and most commonly, making treatment possible in cases involving impacted teeth. This section aims to explain the relationship between orthodontics and oral, dental, and maxillofacial surgery in line with these objectives.

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1. Impacted Teeth

In both general dentistry and orthodontics, the timely eruption of teeth within the expected age range is an important criterion for predicting orthodontic anomalies early on. While chronological or skeletal age can be indicative, the stage of root development is actually more decisive in determining a tooth's eruption status. It is known that a tooth beginning to erupt has typically reached about three-quarters of its final root length (Grøn, 1962). After third molars, the most commonly impacted teeth are canines. According to one assessment, a canine is considered impacted if its root development is complete and its counterpart on the opposite side has erupted at least six months earlier (Aydin et al., 2004; Dachi & Howell, 1961; Lindauer et al., 1992; Thilander & Myrberg, 1973).

Knowing the criteria that define an impacted tooth is crucial to determine the right timing and method for surgical intervention. Even if a tooth doesn't yet meet these criteria, the presence of obstacles like persistent deciduous/supernumerary teeth or pathological formations such as tumors or cysts may pose a future risk of impaction and require early surgical management (Demirel et al., 2019; Hankinson et al., 2024; Mitchell & Bennett, 1992). When such obstructions are surgically removed, the tooth often erupts on its own. If not, orthodontic force can be applied to guide the eruption.

When maxillary incisors are impacted, there are four main techniques to expose them: simple excision (gingivectomy), apically positioned flap (APF), closed eruption technique, surgical replantation (Kokich & Mathews, 2014). For impacted canines, gingivectomy, APF, and the closed eruption method are commonly used. Gingivectomy and APF are classified as open eruption methods (Chaushu et al., 2003). Gingivectomy should only be performed if at least 3 mm of gum tissue remains around the tooth post-procedure. However, since anterior impacted teeth are typically located at or above the mucogingival junction, gingivectomy is often unsuitable and may result in thick, apically positioned, rounded, and anaesthetic gum tissue over the crown. To counter this, the apically positioned flap technique is recommended to ensure a band of keratinized gingiva on the labial side (Vanarsdall & Corn, 1977). However, APF can result in a more apical gingival margin, longer clinical crown, greater attachment and bone loss compared to the closed eruption method (Vermette et al., 1995). Moreover, in terms of recurrence after a certain period of time, re-intrusion is also experienced.

In the closed eruption technique, a flap is raised over the impacted tooth, an orthodontic attachment is bonded to the crown, and the tooth is guided into eruption along the alveolar ridge. This technique's advantages are that it avoids open wounds and dressings, allows alignment during eruption, reduces scarring and periodontal issues, and preserves attached gingiva (Crescini et al., 1994; Sherwood, 2013; Vermette et al., 1995). It is the most common method used for impacted central incisors (Sfeir et al., 2018). Furthermore, Sfeir et al. also note that waiting a while before applying force post-exposure helps supracrestal fibers properly attach to the cementum.

The surgical replantation technique is an option for teeth that are horizontally or inverted vertically positioned within the bone. After flap elevation, the tooth follicle is enucleated and placed in a surgically prepared osteotomy site, ideally just below the occlusal level (Kokich & Mathews, 2014). If root development is still early, this technique may allow the tooth to erupt naturally and complete root formation without orthodontic force (Kuroe et al., 2006). It also provides a way to preserve teeth with root dilacerations that might otherwise need extraction (Tsai, 2002).

2. Orthognathic surgery

Orthognathic surgery refers to the combined orthodontic and surgical treatments aimed at correcting skeletal anomalies in the craniofacial region to restore proper anatomical and functional relationships (Pahkala & Kellokoski, 2007). This type of treatment is typically pursued for individuals with significant jaw deformities, temporomandibular joint disorders, speech problems, chewing inefficiencies, airway issues, or aesthetic concerns (Elsalanty et al., 2007).

While orthodontic treatment can make limited corrections to occlusion, it cannot alter facial aesthetics (Sugawara, 1990). Therefore, cases involving maxillary retrognathia, mandibular prognathism, or combinations of the two may require orthognathic treatment (Athanasiou, 1993; Thilander, 1979). Although bilateral sagittal split osteotomy and Le Fort I osteotomy are the most commonly used techniques today (Proffit et al., 2006), many surgical methods exist for correcting dentofacial deformities. These include: Maxillary Techniques (Surgically Assisted Maxillary Expansion (SARME), Anterior and Posterior Segmental Osteotomies, Le Fort I, II, and III Osteotomies; Mandibular Ramus Techniques (Sagittal Split Ramus Osteotomy, Intraoral Vertical Ramus Osteotomy, Reverse L Osteotomy; Mandibular Corpus Techniques (Anterior Mandibular Subapical Osteotomy (Segmental), Total Subapical Osteotomy, Mandibular Body Surgery (Ostectomy); Genioplasties (Buhara, 2013).

Orthognathic treatments not only correct anomalies but also enhance facial appearance, enabling individuals to be more confident and engaged in daily life.

Some of the above-mentioned surgical methods used in orthognathic treatments are given below.

2.1. Surgically Assisted Maxillary Expansion (SARME)

One of the primary issues affecting the maxilla is transverse maxillary deficiency. Patients with this condition usually present with a narrow palatal arch and often a posterior cross bite (Proffit et al., 2006). The most common treatment to correct this is maxillary expansion (Haas, 1961).

The first maxillary expansion appliance was introduced to the scientific world by Angell in 1860 (Angell, 1860). The modern version of Rapid Maxillary Expansion (RME) was developed by Haas, who created an appliance that bears his name (Haas, 1961). Haas's appliance used both dental anchorage (via bands) and soft tissue support (via an acrylic base). However, due to hygiene difficulties with the acrylic base, Biederman later developed the Hyrax expander, which removed the acrylic base and was more hygienic and thus more clinically preferred (Biederman, 1973). All of the above-mentioned RME techniques can produce skeletal changes in individuals who haven't completed pubertal growth, particularly those whose mid-palatal suture is not yet fully fused. However, in adults, due to the fusion of the suture, these appliances only provide dental changes, with limited or no skeletal effect. To overcome this limitation, Surgically Assisted Rapid Maxillary Expansion (SARME) is used in adult patients. SARME allows for both skeletal and dental changes (Betts, 2016; Woods et al., 1997). With the surgically assisted widening method used, maxillary transversal stenosis cases can be solved by creating both skeletal and dental effects in adult individuals.

In order to perform this procedure, the orthodontist applies the expansion appliance to the patient's mouth before the surgical procedure. After the orthodontist applies the appliance to the patient's mouth, the patient is referred to a musculofascial surgeon and the surgeon performs an incision approximately 5 mm above the horizontal mucogingival junction extending from the first molar to the first molar on the other side. The piriform aperture (apertura priformis), infraorbital nerve and vascular structures and zygomatic process are made visible and a tunnel for dissection is obtained in the pterygomaxillary suture area (Betts, 2016). After this procedure, maxillary release is achieved. Some maxillofacial surgeons, in addition to these procedures, intervene in the palatine suture median and help the expansion process to progress more easily. Classical expansion protocols are applied after the surgery. The patient's recovery period and the treatment period progress in parallel.

2.2. Le Fort I Osteotomy

Le Fort I osteotomy is one of the most frequently used surgical techniques for correcting skeletal deformities in the midface region. It allows the maxilla to be repositioned both aesthetically and functionally. This technique enables movement of the maxilla in three planes (Buchanan & Hyman, 2013); moreover, the maxilla can be moved as a single piece or segmented in both vertical and horizontal planes. The main objective is to separate the maxillary segment that carries the teeth from its connection with the upper maxillary structures. The separated segment must always include the bony palate structure; this is crucial for surgical stability and function (Buchanan & Hyman, 2013; Miloro et al., 2004).

The first Le Fort I osteotomy was performed by von Langenbeck in 1859 to excise nasopharyngeal polyps (Langenbeck, 1859). However, the first true Le Fort I-type maxillary surgery is reported to have been carried out in 1868 by the American surgeon David Williams Cheever (1831–1915) at Boston City Hospital. This procedure is also noted to have been applied to the nasopharyngeal region (Cheever, 1870).

Today, Le Fort I osteotomy is widely used in the treatment of skeletal Class II and Class III malocclusions, maxillary hypoplasia, open bite, and jaw asymmetries (Bell, 1975). This surgical procedure allows for advancement, retraction, inferior repositioning, or superior repositioning of the maxilla. In some patients with asymmetry, these procedures can be done asymmetrically to achieve a more aesthetic appearance.

During the procedure, incisions are made to carefully expose the anterior, lateral, and pterygomaxillary regions of the maxilla. These incisions are typically performed horizontally through the buccolabial mucoperiosteal tissue, parallel to the free gingival margin and above the root apices of the maxillary teeth. The vestibular incision, often extending from the first molar to the opposite molar, can be performed using a scalpel or electro-cautery, depending on the surgeon's preference (Buchanan & Hyman, 2013; Miloro et al., 2004). The osteotomy cut is made approximately 15 mm above the gingival margin and extends forward to the edge of the piriform fossa, passing behind the pterygomaxillary fissure, to avoid the roots of the teeth.

Modifications can be made depending on the specific surgical procedure (Harris & Hunt, 2008).

Le Fort I osteotomy is not only aimed at reshaping the anatomical structure but also constitutes a comprehensive approach that enhances both facial aesthetics and oral functions, making it one of the most preferred procedures for the maxilla in orthognathic surgery.

2.3. Le Fort II Osteotomy

Le Fort II osteotomy is an advanced surgical technique preferred for the aesthetic and functional treatment of various developmental disorders caused by midface hypoplasia. It is especially chosen in cases with flattening or volume loss in the infraorbital region. Compared to Le Fort III osteotomy, Le Fort II has a more limited area of intervention, which makes the surgical procedure less traumatic, and therefore, it is preferred over Le Fort III in selected cases. During the surgical procedure, the maxilla, nasal structures, and a significant portion of the nasal septum are advanced together and rotated along a specific axis to achieve repositioning. This technique aims to increase the anterior projection of the midface and create a more balanced facial contour (Harris & Hunt, 2008).

Access to the surgical site is meticulously ensured by taking into account the frontal and orbital anatomical boundaries. During the mobilization of the anterior segment, careful dissection is performed to avoid damage to the orbital structures, nasal surrounding tissues, and the nasolacrimal system. The target area is exposed by gently elevating the mucoperiosteal layers through horizontal vestibular incisions. Although Le Fort II osteotomy allows for limited repositioning of the maxilla, it is still an effective technique that enables significant aesthetic and functional improvement in the soft tissues and contour profile of the face (Harris & Hunt, 2008).

2.4. Le Fort III Osteotomy

Le Fort III osteotomy is an advanced surgical approach performed in complex cases involving severe maxillofacial hypoplasia and/or craniofacial anomalies. In this procedure, not only the maxilla but also the zygomatic bones, nasal structures, and orbital complex are mobilized together, allowing for a comprehensive forward repositioning of the midface skeleton. Structures such as the globe (eyeball), optic nerve, nasolacrimal duct, and surrounding soft tissues are among the most critical areas that must be protected during the operation. When performed with the Kufner modification, a more balanced and predictable segment movement can be achieved compared to classical methods (Harris & Hunt, 2008).

The osteotomy lines are carefully created to pass through the zygomatic arch, orbital rim, and the frontomaxillary junction. The dissection is performed with high precision to avoid damage to surrounding tissues, and the bone segment is moved forward in a controlled manner using retractors. When necessary, cortico spongious bone grafts are applied to provide structural support. After the osteotomy, stabilization is achieved using miniplates, ensuring successful outcomes both aesthetically and functionally. This technique offers the surgeon a powerful and effective three-dimensional correction tool, especially in cases involving congenital dysmorphisms, severe midface collapse, and complex facial deformities (Harris & Hunt, 2008).

2.5. Anterior Mandibular Corpus Osteotomy

This procedure is typically performed using vestibular incisions made in the first and second premolar region. It may be preferred in Class III anomalies where mandibular prognathism is present, provided there is functional occlusion in the posterior region and/or an anterior open bite is present or absent (Böckmann et al., 2014).

2.6. Posterior Mandibular Corpus Osteotomy

This technique is applied to correct Class III deformities and crossbites in cases where there are missing teeth in the posterior region of the mandible. During the surgical procedure, great care must be taken to protect the neurovascular bundle (Böckmann et al., 2014; Malik, 2012).

In segmental osteotomies performed in the mandible, the mental foramen is used as a reference point. If the incision is made in front of the foramen, it is called an anterior corpus osteotomy; if behind, it is a posterior corpus osteotomy (Malik, 2012).

2.7. Genioplasty

This technique can be performed alone or in combination with other maxillary and/or mandibular osteotomies. Its primary goal is to correct aesthetic concerns related to the chin area. This osteotomy allows movement in three directions, and it can be planned either transversely or vertically.

2.8. Bilateral Sagittal Split Osteotomy (BSSO)

This technique was first developed by Obwegeser and Trauner. One of the biggest reasons it's so commonly preferred is that it is performed intraorally without touching the posterior border of the ramus, which means it doesn't leave visible scars. With bilateral sagittal split osteotomy, the mandible can be moved forward or backward, and asymmetrical corrections and rotational movements can also be performed (Böckmann et al., 2014; Obwegeser, 2007). While it is preferred in mandibular anomalies, the large areas in the incision area and the lack of the need for grafts in mandibular advancement procedures have been effective in the increase in its popularity (Obwegeser, 2007; Pont, 1961).

One of its biggest advantages is that the distal segment is freed up and allowed to move easily. The wide contact surface between the osteotomized segments promotes osteogenic healing and contributes to postoperative stability. Since the masticatory muscles are repositioned close to their original anatomical position, muscle balance is preserved and relapse risk is reduced. Moreover, the low risk of complications has made this application clinically more reliable (Perciaccante & Bays, 2004).

2.9. Distraction Osteogenesis

This method, usually used alongside orthopaedic treatments, aims to reshape both bone structures and surrounding soft tissues by placing a distraction device between separated bone segments after an osteotomy in areas with deficient, short, or discontinuous bones (Dağ et al., 2011; Sailhan, 2011).

First developed by Wassmund and Rosenthal in 1926, this technique has become a routine treatment in cases where new bone formation is needed, and its use in the maxillofacial region has also increased in recent years (Sencimen et al., 2007; Yen et al., 2001).

The basic logic of distraction techniques is based on applying a stretching force to the callus of the bone. However, considering the force applied to the bone growth plates, it is possible to classify them as callotosis and physical distraction (Annino et al., 1994; Dağ et al., 2011). While physical distraction is performed with the forces applied to the bone growth plates (Dağ et al., 2011), callotosis distraction is performed by separating the fractured bone fragments from each other (Imola et al., 2002).

2.9.1. Distraction osteogenesis treatment consists of six main phases (Dağ et al., 2011):

2.9.1.1. Preoperative Phase: General clinical examination of the patient is conducted, and radiodiagnostic evaluations are performed for treatment planning.

2.9.1.2. Operative Phase: The bone segment to be distracted is separated through osteotomy, and the distraction device is fixed to the bone surface.

2.9.1.3. Latency Phase: After osteotomy, a 5–7 day period is given for soft tissue healing and initial callus formation, during which no force is applied.

2.9.1.4. Distraction Phase: The distraction device is gradually activated to pull the bone segments apart. This phase varies depending on the distraction rate, total distraction duration, and distraction rhythm.

2.9.1.4. Consolidation Phase: After distraction is completed, time is allowed for bone mineralization. It usually lasts 4–8 weeks, ideally twice the duration of the distraction phase (Ilizarov, 1988).

2.9.1.5. Retention Phase: The distraction device is removed, and if needed, orthodontic treatment is applied in this phase.

2.9.2. Indications for distraction osteogenesis in the maxillofacial region (Cohen Jr, 2002; Hunt & Flood, 2002):

2.9.2.1. Craniosynostoses (syndromic and non-syndromic)

2.9.2.2. Cleft lip and palate

2.9.2.3. Pierre Robin syndrome

2.9.2.4. Hemifacial microsomia

2.9.2.5. Bilateral pharyngeal arch defects (primary and secondary)

2.9.2.6. Deformities caused by trauma in the maxillofacial region (e.g., accidents, gunshot wounds, physical trauma, etc.)

2.9.2.7. Bone loss due to various causes, such as aging, malignant tumour resections, periodontal diseases, etc.

3. Distraction Osteogenesis Procedures in the Maxillofacial Region

3.1. Distraction Osteogenesis of the Maxilla and Midface

In patients with hypo-plastic maxilla, one of the treatment options is distraction applied to the midface and maxilla. This procedure can be performed independently of the mandible, and the applied force can be controlled in three dimensions (Samchukov & Cope, 2001).

In these cases, Rigid External Distraction (RED) is used. To perform this, the maxilla is first mobilized using a Le Fort I osteotomy (or its modifications). Following the osteotomy, the RED technique is applied to carry out the treatment (Samchukov & Cope, 2001).

Another method of distraction in the maxilla is called transpalatal distraction. This technique is used to correct transverse maxillary deficiencies of various causes via distraction osteogenesis (Mommaerts, 1999).

3.2. Mandibular Distraction Osteogenesis

Mandibular distraction is a technique often preferred in patients with mild asymmetries, severe mandibular deficiency, and/or mandibular hypoplasia (Kolstad et al., 2011). It's especially recommended in individuals whose hypo-plastic mandible is too underdeveloped to be corrected through orthognathic treatment alone.

The distractors used in this procedure are multifunctional, meaning they allow movement in all three planes. Mandibular distractors can be used not only for advancing a retrognathic/hypoplastic mandible, but also in cases involving anterior open bite (Dağ et al., 2011).

3.3. Alveolar Distraction Osteogenesis

Alveolar distraction osteogenesis is an effective surgical approach for the rehabilitation of various alveolar bone deficiencies. It is particularly preferred in cases where crest atrophy exceeds 4 mm, resulting in functional and aesthetic limitations for implant placement. In cases where the segmental alveolar ridge is insufficient and a proper crown–implant relationship cannot be achieved; in narrow alveolar bone structures that allow horizontal distraction; and in situations where tooth movement via orthodontic methods is either impossible or has failed—especially in the treatment of ankylosed teeth requiring gradual vertical mobilization—this method offers significant advantages. Furthermore, alveolar distraction osteogenesis is beneficial in cases requiring the vertical repositioning of osseointegrated implants together with the surrounding alveolar bone, in the rehabilitation of limited edentulous spaces (between two to four teeth), in tissue loss caused by traumatic events, in tooth loss due to periodontal disease, and in the reconstruction of congenital malformations. In all these scenarios, alveolar distraction osteogenesis has been clinically proven to be an effective treatment alternative (Annino et al., 1994; Hönig et al., 2002; Sailhan, 2011; Tavakoli et al., 1998).

3.4. Cleft Lip and Palate

The maxillofacial system develops between the 4th and 12th weeks of intrauterine life. During this period, various environmental, genetic, and/or etiological factors can disrupt embryonic development, resulting in the formation of cleft lip and/or palate (Nagase et al., 2010). In Türkiye, cleft lip and palate occur in 1 out of every 1,000 births, while globally, the incidence is around 1 in every 800–1,000 births (Tanaka et al., 2012; Yılmaz et al., 2019). Clefts are three times more common in males than in females (Shapira et al., 1999), and unilateral clefts occur three times more frequently than bilateral clefts (Shapira et al., 1999; Yağcı & Uysal, 2007).

Clefts may affect only the lip, only the palate, or occur as unilateral or bilateral combinations of both. Various classification systems exist for clefts. The first was developed in 1922 by Davies and Ritchie, categorizing clefts as prealveolar, postalveolar, and alveolar (Davis & Ritchie, 1922). In 1931, Veau based his classification on anatomical structures: soft palate and uvula; soft palate–hard palate and uvula; unilateral complete cleft of lip–alveolus–hard palate–soft palate and uvula; and bilateral clefts involving the same structures (Veau, 1931).

By 1958, cleft classification shifted to an embryological development model. Kernahan and Stark introduced a model based on primary and secondary palates, with distinctions for unilateral/bilateral and complete/incomplete clefts (Kernahan & Stark, 1958). In 1971, Kernahan added the famous striped "-Y-" diagram to improve data transfer and visualization (Kernahan, 1971).

This model was later modified by Elsahy in 1973, who added components such as the posterior pharyngeal wall, nasal floor, and premaxilla (Elsahy, 1973). In 1977, Millard contributed by adding inverted triangles to the striped "-Y-" to represent nasal alar deformities (Millard Jr, 1977).

By 1991, Friedman and colleagues, inspired by Elsahy and Millard's systems, added velopharyngeal closure and prolabium (Friedman et al., 1991). Around the same time, Otto Kriens developed a more user-friendly classification system based on "LAHSHAL" (Kriens, 1989). Later in 2009, Percy Rossell-Perry introduced the "Clock Diagram" classification system (Rossell-Perry, 2009).

3.4.1. Treatment Methods for Cleft Lip and Palate:

Treatment for individuals with cleft lip and palate begins from birth. To ensure that babies can feed properly, feeding plates are initially fabricated by orthodontists, allowing the infant to receive adequate nutrition. The goal here is to help the baby reach ideal weight and blood values for surgery (Erverdi, 2017). These plates are adjusted monthly to accommodate the child's growth.

After the initial feeding plate, appliances are used for nasoalveolar moulding, which help shape the nose and soft tissues. Additional attachments are placed on these plates to mould the nasal structures and bring the tissues closer together, thereby improving surgical outcomes and stability (Bennun et al., 2016).

Once babies reach a suitable weight and blood profile, surgeries begin, starting with soft tissues. Typically, the first lip surgery is performed between 2–5 months of age. The current approach is to perform a single surgery to close the palate defect during the 6–9 month range, which aligns with the phonation period (Bennun et al., 2016).

However, surgery timelines can vary depending on the complexity of the case, the baby's development, and tissue response.

Due to the surgeries performed during infancy, scar tissue inevitably forms, which can result in abnormal tooth eruption and/or maxillary growth anomalies. Therefore, these individuals must be followed from infancy to adulthood for ongoing evaluation and correction.

Initially, the eruption of teeth and presence of missing teeth should be monitored. During this stage, the potential for maxillary deficiency should be assessed, and if necessary, functional appliances such as face masks or Frankel III devices should be used (Dogan, 2012; Sahoo et al., 2023). If the growth phase has ended and the anomalies couldn't be corrected with functional treatments, orthognathic surgery should be considered (Posnick & Tiwana, 2006; Zaroni et al., 2024).

In children who drop out of follow-up care or are not properly monitored, oroantral fistulas may remain in the cleft line (Arthur et al., 2005). Such conditions can still be treated with the collaboration of orthodontists and oral and maxillofacial surgeons.

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Chapter 8

Holistic Approach in Orthodontics and Prosthodontics

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Abstract

Multidisciplinary approaches in dentistry are essential for achieving optimal results. The collaboration between orthodontics and prosthodontics is particularly crucial in advanced and difficult cases. In this context, the cooperation of these fields ensures optimum aesthetics and function in cases such as tooth deficiencies, malocclusions, loss of vertical dimension, excessive tooth wear, and overturned molars. Achieving the ideal tooth position prosthetically in difficult cases, such as overturned, malposed, or crowded teeth, is only possible with an orthodontic intervention performed beforehand. Nowadays, orthodontics and prosthetics cooperation has become digital thanks to advanced digital dentistry. Contemporary approaches such as digital planning, CAD/CAM technology, clear aligners, and piezocision make the treatment process more predictable and patient-oriented. This method facilitates the establishment of interdisciplinary relationships and actively involves the patient in the treatment process. Consequently, for effective treatment, it is essential that the orthodontist and prosthodontist together devise a strategy, coordinate patient follow-up, and involve the patient in the treatment process.

Introduction

Orthodontic treatment is a method that enhances the efficacy and adaptability of prosthodontic treatment by facilitating the alignment of the teeth and jaws in the most suitable position. Prosthodontic treatment is critical in terms of occlusion regulation, rehabilitation of missing teeth, and

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parallelism of the roots in orthodontic rehabilitation patients (Spalding & Cohen, 1992).

Multidisciplinary treatment planning is important for obtaining the most optimal result by considering the case in terms of different disciplines rather than a unidirectional perspective. A multidisciplinary approach in the management of complicated prosthetic cases leads to successful aesthetic and functional results. This methodology ensures optimization of treatment time, the best approach for aesthetic appearance, and longer-lasting restorations (Geckili et al., 2011).

1. Compatible Planning of Orthodontic Treatment and Prosthetic Restoration

A multidisciplinary cooperation between prosthodontics and orthodontics is necessary for a more aesthetic and functional treatment (Happe et al., 2023). The dental design created after orthodontic treatment allows for a more natural smile (Kuljic, 2008). Such interdisciplinary cooperation is becoming increasingly popular and has led to the concept of prosthodontics-guided orthodontics (PGO) (Blasi et al., 2022). Before digital tools were available for planning orthodontics and prosthetics, PGO was a process where it was very hard to get the best treatment results and see how the teeth would move without working closely with the prosthodontist (Kuliš et al., 2024).

1.1. Orthodontic intervention prior to prosthesis

It is crucial that all dental treatments are completed by obtaining healthy tissues before prosthetic treatment. Moreover, prosthodontic treatment requires a multidisciplinary approach, since the condition of the teeth must be in harmony with the surrounding tissues in the jaw, joint, and facial region. Prosthodontic and orthodontic dentistry should collaborate in specific circumstances. A few of these are described below.

Multiple missing teeth: The presence of more than one toothless cavity necessitates changes to the treatment process. There are many factors to consider here. The patient's financial circumstances, the state of the supporting teeth, and the bite relationships, etc. The orthodontist can be involved in the final restoration planning process. Different approaches exist for applying prosthetic treatment, such as narrowing or expanding the edentulous space. This approach decision also determines the final prosthetic planning (Pinho et al., 2012; Uribe et al., 2013). In such cases, the reduced number of teeth will limit anchorage. The orthodontist has to employ temporary anchorage devices to provide anchorage or place the implant(s) before or during orthodontic treatment in cases where implant-supported prostheses are planned as the final treatment (Alfallaj, 2020; Pinho et al., 2012)

1.2. Excessive Vertical Overbite Cases

Vertical overlap (overbite) is defined as the distance that the upper anterior teeth cover the lower anterior teeth (Edition, 2017). Coverage varies in healthy individuals (Akerly, 1977). As the amount of overbite increases, the amount of force on the teeth, soft tissue irritations, and the tendency to wear on the teeth tend to increase. Such conditions may complicate the provision of aesthetics and function in prosthetic restorations (Beddis et al., 2014). These cases can be treated restoratively, orthodontically, surgically, or multidisciplinarily. Modifying the occlusal surfaces of the teeth in restorative treatment can increase the vertical dimension (Ergun & Yucel, 2014) (Beddis et al., 2014). In orthodontic treatment, intrusion of anterior teeth, extrusion of posterior teeth, use of implant-supported anchorage, or a combination of these methods can be used. However, extrusion of the posterior teeth is more likely to recur, as the contraction of the masticatory muscles can return the posterior teeth to their original position. Therefore, segmented intrusion of the anterior teeth is preferred in adult patients (Weiland et al., 1996). In such patients, implant anchorage helps the intrusion of anterior teeth by providing absolute anchorage. In surgical treatment, mandibular sagittal split osteotomy can be used (Ishihara et al., 2014).

For cases of excessive vertical overbite, Kokich proposed the following approach.

1.2.1. Determination of the Occlusal Plane: First, the occlusal plane should be determined on the cephalometric radiograph. For this, the contact points of the maxillary-mandibular 2nd molars in the posterior and the tip of the upper lip in the anterior should be considered.

1.2.2. Determining whether the etiology depends on overbite: Clinicians evaluate the relationship of the maxillary and mandibular anterior teeth with the correct occlusal plane to determine the source of deep vertical overbite. This assessment is done by measuring the distance of the incisal edge of the maxillary central incisor from the occlusal plane. This distance should be 2 to 3 mm lower in young individuals and shorter in older individuals. If the distance exceeds these values, the maxillary anterior teeth may be the source of the deep bite. The incisal edge of the mandibular anterior teeth must align with the occlusal plane; if these teeth are above this plane, they are considered over-erupted and may require intrusion.

1.2.3. Evaluation of Gingival Margin Position: If the gingival margins of the central incisors are coronal to the canines, the cause of this should be investigated. If the enamel-cementum junction is within 1 mm and the anterior teeth are worn, intrusion of the teeth may be necessary. If the enamel-cementum junction is within 1 mm and the anterior teeth are worn, intrusion of the teeth may be necessary. Before any orthodontic treatment is performed, restorative dentists and orthodontists should agree on a specific treatment plan and use the gingival margins (not the incisal edge) as a reference for tooth intrusion, especially if the patient shows a high smile line.

1.2.4. Surgical Necessity: Orthodontic treatment alone is sufficient for most patients with excessive anterior deep closure. However, in patients with severe facial disproportion, surgical intervention is required to correct excessive vertical overlap (Kokich, 2008).

1.3. Excessively Worn Anterior Teeth

An additional significant concern necessitating a multidisciplinary approach is the excessive wear of the anterior teeth resulting from anterior bruxism. The reason why this situation turns into a complex problem is the excessive shortening of the anterior teeth while the crown length of the posterior teeth remains normal. In this case, the anterior teeth will erupt together with the soft tissue and bone, and contact with the opposing teeth will be preserved. This will lead to the formation of short clinical crowns and incompatible marginal gingiva (Kokich, 2008; Turner & Missirlian, 1984a).

This problem can be solved by orthodontic intrusion of posterior teeth for restoration of worn anterior teeth, surgical extrusion of worn anterior teeth, space gain as a result of occlusal restoration of posterior teeth, or the use of the Dahl concept.

Orthodontic intrusion protects tooth structure; it does not necessitate incisal reduction or extensive preparation. It creates an aesthetic appearance by aligning the gingival margin (Alfallaj, 2020). However, it requires patient compliance due to apical root resorption and prolonged treatment (Bellamy et al., 2008).

Surgical extrusion of teeth is advantageous as it reduces the time required and enhances the retention area for the restoration. In addition, the short treatment time does not require extra patient compliance. However, it also has disadvantages. However, the method is invasive, it changes the balance between the crown and root, can cause dental sensitivity because the root surface is exposed, and can lead to black triangles appearing on the gingiva (Kokich, 2008; Saha & Summerwill, 2004).

The occlusal vertical dimension can be increased by restoring the posterior teeth in one or both arches, thus creating adequate restorative space for the worn anterior teeth. However, adaptation of the patient to the new occlusion will take time (Kokich, 2008; Turner & Missirlian, 1984b).

Dahl Concept: It is a minimally invasive technique used to create an intermaxillary space in the anterior field. In this concept, an appliance is used that covers the palatal surface of the anterior teeth, thereby disoccluding the posterior teeth and allowing the posterior teeth to erupt. In this way, a space for restoration is created in the anterior area (Dahl et al., 1975; Hemmings et al., 2000; Poyser et al., 2005). This method has some disadvantages, such as the patient's difficulty in chewing and speaking, the occlusal force applied to the anterior teeth causing periodontal and endodontic complications, and the indefinite duration of use of the appliance (Poyser et al., 2005).

1.4. Uprighting of Tilted Molars

Uprighting of Tilted MolarsTilted posterior teeth, typically resulting from tooth loss or significant caries, might complicate restorative operations, particularly when mandibular second molars tilt following the loss of first molars (Stern et al., 1981). Tilting frequently leads to mesial infrabony deformities and a heightened risk of periodontal problems. Treatment alternatives encompass enameloplasty for mild cases, the application of locking attachments or telescopic crowns, and orthodontic uprighting (Revah et al., 1985). Orthodontic treatment improves occlusal alignment, facilitates prosthetic preparation, and increases force distribution (H. Kumar & Vijayalakshmi, 2009) Fixed appliances offer precise movement with adequate anchorage, while removable appliances rely on patient compliance and provide limited movement. The average treatment time is approximately 3 months, depending on tooth angulation, root length, and periodontal health (Alfallaj, 2020).

1.5. Orthodontic Crown Lengthening

Orthodontic extrusion is a conservative alternative to surgical crown lengthening treatment. It is particularly useful in cases involving subgingival caries, deep restorations, or fractures that compromise biological spacing. Maintaining restoration margins within 0.5-1 mm of the gingival sulcus and at least 3 mm above the bony crest is essential for periodontal health (Baba et al., 2014). In the cases with subgingival caries, deep restorations, or subgingival defects, the patient may be referred for clinical crown lengthening to prevent invasion of the restoration into the biological width. In this case, the clinician should choose one of two methods: surgical crown lengthening or orthodontic crown lengthening with rapid and high extrusion forces that may cause tooth movement without an attachment appliance (Alsahhaf & Att, 2016). Compared to surgical methods, orthodontic extrusion offers several advantages: It improves the crown-to-root ratio, avoids compromising the alveolar bone of neighboring teeth, and better preserves aesthetics, especially in the anterior region. However, extrusion can cause coronal movement of both gingiva and bone, sometimes requiring subsequent corrective surgical crown lengthening (Potashnick & Rosenberg, 1982). Fiberotomy, including intrasulcular incisions and weekly root trimming, can reduce the need for post-treatment corrective surgery by preventing unwanted bone formation above the fiber attachment (Alfallaj, 2020).

Orthodontic extrusion treatment starts with endodontic intervention, succeeded by the implantation of a post, core, and temporary crown. We initiate extrusion with a force of 50 grams weekly, aiming for a movement of 1 mm per week. After achieving the correct dentogingival relationship, we stabilize the tooth for 6 to 8 weeks to allow for bone remodeling before applying the final restoration. Restorative procedures need to be planned carefully because the final crown has to fit the narrower root, finding a balance between too much shaping that can harm gingival health and tapering that can cause aesthetic issues like gaps between the teeth (Ingber, 1976).

2. Multidisciplinary Approach to Amelogenesis Imperfecta Patients

Amelogenesis imperfecta (AI), or congenital enamel hypoplasia, impairs the formation of enamel structure. The majority of AI cases result from mutations in genes that encode enamel matrix proteins, which are essential for the initiation, elongation, and organization of enamel mineralization (Kim et al., 2017). Patients with hypomature AI have clinically rough and pitted tooth surfaces, tooth sensitivity, and discoloration. Due to this nature, they have easy aligner retention and high caries incidence. In addition to these characteristics, short clinical crown length, malformed teeth, excessive or incomplete tooth formation compared to the dental arch, pulp calcifications, taurodontism, root malformations, anterior open bite, and abnormal growth of the maxilla and mandible can be observed (Alachioti et al., 2014;

Poulsen et al., 2008; Strauch & Hahnel, 2018a). The abnormal growth of the maxilla and mandible does not alter the occlusal vertical dimension and has minimal or no effect on the restorative space of the posterior teeth; however, it creates a significant restorative space in the anterior region due to the open bite. Optimal treatment usually includes both occlusal vertical dimension increase and clinical crown lengthening procedures. The increase in occlusal vertical dimension should be done by taking into account the amount necessary to organize the short posterior teeth. Otherwise, excessive anterior crown heights may be created, and the crown-root ratios of the teeth may reach dangerous levels (Ortiz et al., 2019).

It is necessary to have a multidisciplinary approach to treatment management. At least one pediatric dentist, orthodontist, and prosthodontist are required (Council, 2013). If the cases are presented to the clinic during the deciduous period, the main goals of treatment are to reduce sensitivity and pain, provide preventive care for caries, protect teeth until permanent teeth erupt, and offer a suitable environment for skeletal growth (Chen et al., 2013). Furthermore, minimizing psychological negativities is one of the important contributions of the treatment (Council, 2013). It is difficult to maintain oral hygiene in such cases. In these situations, stainless steel crowns or glass ionomer restorations can be used for back teeth, and composite resin crowns for front teeth to help prevent cavities and enamel wear while also looking good (Chen et al., 2013; Council, 2013; McDonald et al., 2012).

The main goals of treatment in patients in the mixed dentition period are to preserve the vitality and integrity of the tooth and to meet aesthetic and functional requirements. During this period, dental evaluation by an orthodontist and prosthodontist is mandatory upon eruption of the permanent first molars and anterior teeth (Chen et al., 2013). Stainless steel molar crowns and glass ionomer restorations can be used until all teeth are fully erupted. This method provides some protection against wear and caries until the teeth fully erupt. In the same way, anterior composite restorations provide protection. However, it is important to note that the edges of the restoration may be visible during tooth eruption, necessitating further procedures for aesthetic enhancement of the restoration (Chen et al., 2013).

Orthodontic evaluation at an early age is critical for the treatment success and overall management of patients with AI. Nonetheless, traditional fixed orthodontic procedures pose certain difficulties for people with AI. Securely bonding brackets to defective enamel is difficult. Defective enamel/dentin may cause durability problems during tooth movement. There is a high risk of damage to tooth tissue during bracket removal (Arkutu et al., 2012; Chen et al., 2013).

Orthodontic treatment with clear aligners may be advantageous for individuals with AI. It can reduce sensitivity by creating a pseudo-coating on the defective enamel/dentin. It may improve the patient's quality of life (Sawan, 2021).

The goals of orthodontic treatment in AI patients are different from normal. The goal is not perfect occlusion. It is to optimize aesthetics, function, and restorative fit. The final prosthodontic treatment plan is organized in accordance with the orthodontic goals.

The main goals of AI treatment during the permanent teeth phase are to restore how the teeth bite together, enhance appearance, and reduce tooth sensitivity. Prosthetic full-mouth rehabilitation should be planned once the gingival tissues have matured and the clinical crown height has stabilized. Crown lengthening and gingival contouring may be required in cases of gingival hyperplasia or shortened crowns. If the structural integrity of the teeth is compromised, endodontic treatment or extractions may be required. Given the prevalence of skeletal disorders and malocclusions, orthodontic treatment is essential; in more severe cases, orthognathic surgery may be necessary (Chen et al., 2013; Möhn et al., 2021). The AI subtype, the patient's psychosocial status, and the patient's existing healthy dentition influence the treatment plan during the permanent dentition phase (Lindunger & Smedberg, 2005).

Subtype is important in AI patients. Orthodontic treatment planning may vary according to the subtype. Planning to close the interdental spaces in the hypoplastic type may result in a reduction in the crown size. Accordingly, further preparations may be required. This results from the need to prepare a suitable restoration surface because the enamel thickness is not normal. In the hypomature type, the enamel thickness is normal. Therefore, closing the gaps does not adversely affect restorative planning (Pousette Lundgren et al., 2015). The enamel in AI patients limits the use of brackets when orthodontic therapy requires them. The most important reason for the limitation is the lack of intact enamel to bond the brackets. Defective enamel is not suitable for brackets. Another reason for orthodontic treatment refusal is the long duration of treatment (Ortiz et al., 2019). You can use orthodontic treatment if the enamel is favorable or if you perform orthodontic treatment independently of the enamel (S. Kumar & Gupta, 2009).

Although prosthodontic treatment aims to provide lifelong function, aesthetics and proper occlusion, various difficulties are encountered in achieving the desired result. While conservative treatment is always the goal, a large amount of preparation and tooth extraction may be planned when necessary. This is more common in younger patients who have not received any orthodontic treatment (Patel et al., 2013).

While removable prostheses were used in the past in such cases, they are not preferred today. The psychological effects of removable prostheses in young patients and the restorative and digital advances in modern dentistry have led to the evolution of treatment planning. Even in cases where restoration of all teeth is not possible, we should consider implant treatment. If there is no suitable bone tissue, bone grafting can be performed (Patel et al., 2013). For restorable teeth, composite resins, porcelain veneers, stainless steel crowns, and CAD/CAM polymers may be preferred (Canger et al., 2010; Patel et al., 2013; Saeidi Pour et al., 2015).

Treatment planning should consider the subtype of AI and tooth structure problems, as these factors have a direct effect on the restoration's lifetime and bonding success.

- Hypoplastic AI: Even if the amount of enamel is small, the bond quality is usually acceptable; however, pitted enamel should be completely removed.
- Hypomaturation AI: Poor enamel quality, high risk of edge leakage, fracture, and abrasion due to porous structure; therefore, defective enamel must be completely removed.
- Hypocalcified AI: It has the poorest enamel quality and poor bonding success; in this type, the restoration may fail if the defective enamel is not completely removed.

Therefore, placement of restorative margins in a solid and healthy structure is critical for the success of the treatment (Chen et al., 2013).

In patients with AI in the permanent dentition, fixed treatment with full crowns is recommended to ensure functional occlusion and aesthetics with an appropriate occlusal vertical dimension. These restorations promote oral hygiene with reduced sensitivity due to enamel defects. Clinical studies have shown that indirect restorations last longer in AI patients (Strauch & Hahnel, 2018b). Studies have also reported that fixed crown restorations significantly reduce gingival infection and bleeding (Pousette Lundgren et al., 2015). While metal-ceramic crowns are commonly used, glass-based all-ceramic restorations are also preferred nowadays (Ozturk et al., 2004; Siadat et al., 2007). However, although these restorations are more conservative restorations, there may be difficulties in masking discoloration due to enamel irregularities (Patel et al., 2013).

Early detection and appropriate treatment at a young age are crucial for long-term dental health and successful rehabilitation. Most of the reported literature on patients with AI are case reports, and there are hardly any studies examining long-term full-mouth rehabilitation in patients with AI. However, one retrospective study indicated that restorations were successful and patients had positive experiences with prosthetic rehabilitation (Lindunger & Smedberg, 2005).

Consequently, long-term follow-up is necessary for AI patients. With accurate diagnosis and treatment, AI may significantly improve patients' quality of life. The majority of the studies comprise case reports. Consequently, additional investigation is necessary. AI patients necessitate continuous care and meticulous monitoring from childhood to adulthood at every phase of treatment.

3. Digital Planning and approaches

Modern orthodontics and innovations in fixed orthodontic appliances have made significant advances in both biomechanical and aesthetic aspects. The main aim of research addressing the aesthetic concerns raised by fixed orthodontic appliances is to make patients feel more comfortable and confident throughout treatment.

Rapid advances in digital technologies and new materials have been a feature of dentistry recently. Prosthodontic treatments have shifted to minimally invasive procedures that achieve a natural and aesthetic appearance for restored teeth (Blatz et al., 2019).

Current digital advances allow visualization of the outcome of prosthetic treatment. Also, recent advances in orthodontic dentistry allow orthodontic tooth movements to be visualized by computer and the final treatment result to be shared with the patient and the dentist. Besides, clear aligners that are designed and manufactured with computer-aided design have been developed (Barreto & Santos, 2018).

3.1. CAD/CAM and Piezocision Effect in Orthodontics

CAD/CAM systems have a wide range of applications in orthodontics. Traditional brackets, clear aligners, and other orthodontic appliances can be designed and manufactured using virtual models. The integration of

3D technology enables the analysis of root inclination and alveolar bone thickness using tomographic pictures; hence, optimizing interdisciplinary treatments such as orthognathic surgery(Cunha et al., 2021).

A study presents an innovative digital constructor for the production of functional orthodontic appliances with CAD/CAM technology. This new approach aims to overcome the difficulties faced in traditional manufacturing processes, enabling faster, personalized, and more efficient production of orthodontic appliances by taking advantage of the possibilities of digital technologies. However, the feasibility of this new concept was evaluated, taking into account the difficulties of existing methods and the limitations of material options. The study demonstrated the construction of a functional appliance using digital models following intraoral scanning of the patient. In this way, it was said that the appliance construction, which would take a long time with the traditional method, could be done effectively and faster with digital methods (Roser et al., 2025).

In another meta-analysis, brackets produced digitally with the CAD/CAM method and brackets produced with the traditional method were compared. Consequently, the study concluded that brackets manufactured using CAD/CAM technology led to an average decrease in treatment duration of four months and that the production process was easier and shorter (Bardideh et al., 2024).

In another study, the effect of CAD/CAM customized orthodontic appliances and piezo-assisted decortication (piezocision) on orthodontic treatment time was investigated, focusing on the alignment and fine-tuning phases. Both technologies significantly reduced orthodontic treatment time; piezocision accelerated the alignment phase, while CAD/CAM appliances shortened the fine-tuning phase. The combination of both methods resulted in the fastest orthodontic treatment.

Piezocision Effect: By using the Regional Acceleration Phenomenon, a biological reaction to bone injury, piezocision significantly accelerated the alignment phase (RAP). However, this acceleration is temporary and lasts 4 to 6 months postoperatively. A second piezocision procedure may be considered to maintain acceleration throughout the fine-tuning phase, but further studies are needed to evaluate its benefits and potential risks.

Effect of the CAD/CAM System: The CAD/CAM system has enhanced the fine-tuning phase by providing precise treatment plans and improving the overall workflow. The system allows for a customized approach, including the creation of digital setups, customized brackets, and archwires.

This increased accuracy reduces the time required for the fine-tuning phase, resulting in a more efficient treatment compared to conventional methods.

Combined Approach (CAD/CAM + Piezocision): The combination of CAD/CAM and piezocision significantly accelerated orthodontic treatment, and the total treatment time was twice as fast compared to conventional methods. This combined approach has provided excellent results for patients with moderate crowding without compromising periodontal health (Charavet et al., 2021).

3.2. Digitally Clear Aligners

The production of clear aligners widely uses digital technologies, which also speed up the treatment simulation process. However, virtual tooth movements can sometimes be unrealistic. Therefore, we advise clinicians to obtain additional information about aligner biomechanics and exercise caution regarding anchorage, progressive movements, and auxiliary mechanics (Barreto & Santos, 2018).

Invisalign is an orthodontic treatment method consisting of transparent aligners used to straighten teeth. It substitutes traditional metal braces and offers an aesthetic alternative. The Invisalign® method, which involves a digitally designed and treated procedure, is an aesthetic option for orthodontic treatment and is particularly suitable for adults and adolescents who have fully erupted teeth. More complex malocclusions present limitations, but simple and intermediate cases that do not require tooth extraction yield the best results. The difficulty of some tooth movements performed with this method does not prevent Invisalign® from being fully utilized, as it can be used in conjunction with conventional appliances. Additionally, you can add customized attachments or composite materials to the appliance to achieve the desired tooth movements. Numerous sources have listed many advantages and disadvantages of the method. Table 1 (Melkos, 2005)

Table 1.

Advantages of Invisalign®	Disadvantages of Invisalign®
Ideal Aesthetics	Limited control over root movements
Ease of use for the patient	Limited intermaxillary correction (severe skeletal disorders cannot be corrected with Invisalign® alone)
Easy to use	Lack of physician control (no possibility to modify the appliance during the treatment process)
Ease of care and better oral hygiene	In the event that any changes need to be made after the start of treatment, additional time and/or documentation may be required
Potential metal allergies seen with fixed orthodontic appliances are eliminated	Mild intrusion (0.25-0.5 mm) of the posterior teeth may occur (this is corrected during the retention period)
Elimination of difficulties in bonding fixed appliances	
Detailed evaluation of treatment options before starting treatment	
The virtual treatment model can be a motivational tool for the patient	

Table 1 (Advantages And Disadvantages of Invisalign)(Melkos, 2005)

Conclusion

The combination of orthodontic and prosthodontic treatment modalities requires a multidisciplinary approach to address complex dental problems. Orthodontic treatment creates the most appropriate basis for prosthodontic rehabilitation by facilitating the correct alignment of the teeth, thus providing both functional and aesthetically effective results. Prosthetic restorations applied without the necessary orthodontic intervention negatively affect the treatment process and success.

Prosthetic treatment planning has an important role in guiding orthodontic treatment. Prosthodontic treatment can regulate conditions that affect orthodontic movements, such as tooth size regulation and occlusion regulation. Accordingly, effective communication and treatment coordination between both specialties directly affect the success of patient management.

Consequently, collaboration between the disciplines of orthodontics and prosthodontics reduces treatment time and provides success in terms of long-term biocompatibility, function, aesthetics, and needs fulfillment. Therefore, a common view of the treatment protocol, especially in the management of interdisciplinary cases, is key to clinical success. The integration of orthodontic and prosthodontic treatment approaches reveals the requirement of a multidisciplinary approach in solving complex dental problems.

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