Orthodontics: Theory, Methodology and Practice

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CHAPTER 1

Local Anaesthesia Techniques in Dentistry: Current Approaches and Clinical Applications

Fatma Selenay Uçaş-Yıldız[1] & Kazım Kaan Yıldız[2]

1.INTRODUCTION

Local anaesthesia in dentistry is an indispensable component of modern treatment approaches. It constitutes one of the most critical steps in terms of increasing patient comfort, providing a painless treatment and performing dental procedures safely. In cases where local anaesthesia cannot be administered or is inadequate, many treatments, from simple restorative procedures to extensive surgical interventions, cannot be performed (Decloux & Ouanounou, 2020).

The use of local anaesthesia in dentistry started in the 19th century with the discovery of cocaine and its introduction into clinical practice, and then accelerated with the development of safer synthetic agents. Currently, agents such as lidocaine, articaine and mepivacaine are the most commonly used local anaesthetics with high efficacy and safety profiles. These pharmacological advances, combined with the diversification of infiltration and nerve block techniques, have significantly enriched clinical practice (Becker & Reed, 2012).

Local anaesthetic techniques play a central role in eliminating pulp sensitivity in endodontic treatments, painless manipulation of tissues in periodontal surgeries, reducing trauma in oral surgical procedures and increasing patient comfort in prosthetic applications. Choosing the right technique directly affects not only the success of the procedure but also the patient's level of anxiety and compliance with the treatment (Mathison & Pepper, 2025).

On the other hand, failure of anaesthesia or development of complications may put the clinician in a difficult situation. Anatomical variations, pharmacological differences, systemic risk factors and patient-specific physiological responses are among the reasons for failure. The clinician must therefore not only be skilled in its application, but also in the scientific basis of local anaesthesia and the management of possible complications (Badr & Aps, 2018).

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In this chapter, local anaesthesia techniques used in dentistry will be examined in detail starting from their historical development within the framework of current pharmacological approaches, application methods, clinical indications and complication management. Thus, it is aimed to provide the reader with not only theoretical knowledge, but also a comprehensive road map that can be applied in daily practice (Ho et al., 2021).

1.1 Importance of Local Anaesthesia in Dentistry

Local anaesthesia in dentistry is a key determinant of treatment success as well as patient comfort. Elimination of pain sensation in dental procedures not only enables surgical and conservative interventions to be performed, but also increases patient compliance with treatment. In patients with poor pain control, even a simple filling procedure may become challenging and the duration of treatment may be prolonged, reducing clinical efficacy (Decloux & Ouanounou, 2020).

The importance of local anaesthesia is not limited to the relief of pain during the procedure. Effective anaesthesia reduces dental anxiety, enhances physician-patient communication and positively influences patient perception of future dental treatments. Furthermore, successful anaesthesia in paediatric patients can positively shape lifelong oral health behaviours by making children's dental experiences less traumatic.

1.2. Historical Development and Pharmacological Basis

The use of local anaesthesia in dentistry dates back to the late 19th century. In 1884, Carl Koller's use of cocaine in ophthalmic surgery is considered to be the beginning of the era of local anaesthesia. However, the addiction and toxicity potential of cocaine soon led to the search for safer agents. In 1905, the synthesis of procaine enabled the safe use of local anaesthesia in dental applications. The development of amide group agents from the 1940s onwards laid the foundation for the modern local anaesthetics used today (Mathison & Pepper, 2025).

Pharmacologically, local anaesthetics inhibit the depolarisation of the nerve cell by blocking voltage-gated sodium channels. This mechanism interrupts the transmission of pain sensation along the nerve fibre. The duration and onset of action are related to the chemical properties of the agent. Lipophilic properties facilitate the passage of the drug across the nerve membrane, while the pKa value determines the proportion of the non-ionised form of the drug and thus the onset of action. In addition, protein binding capacity prolongs the duration of action by enabling the drug to bind in the nerve tissue.

1.3. Local Anaesthetic Agents Used

Local anaesthetics used in dentistry are divided into two main groups: esters and amides. Ester group agents (procaine, benzocaine) are mostly used for superficial anaesthesia, while amide group agents (lidocaine, articaine, mepivacaine, prilocaine, bupivacaine) are the main group preferred in clinical applications (Gazal, Omar, & Elmalky, 2023).

- Lidocaine: Synthesised in 1943, it is still the most widely used agent due to its rapid onset of action and intermediate duration of action.

- Articaine: Thanks to its high lipophilicity and thioester structure, it diffuses better through bone, and its efficacy is high in mandibular posterior regions.

- Mepivacaine: Since its vasodilator effect is low, vasoconstrictor-free form can also be used safely.

- Prilocaine: Although it has a low toxicity profile, it carries the risk of methaemoglobinaemia at high doses.

- Bupivacaine: Due to its long duration of action, it is especially preferred to provide analgesia after surgery.

Vasoconstrictor additives (e.g. adrenaline) increase the efficacy of local anaesthesia, prolong its duration and control bleeding. However, it should be used with caution in patients with cardiac problems (Ghafoor et al., 2023).

1.4. Local Anaesthesia Techniques

Local anaesthesia techniques applied in dentistry vary according to anatomical structure and procedure type (Ogle & Mahjoubi, 2012).

- Infiltration anaesthesia: It is often preferred because the cortical bone in the maxilla is thin. The solution is injected directly into the target area and the nerve endings are blocked.

- Nerve block (conduction) anaesthesia: It is more effective because the cortical bone is thicker in the mandible. Inferior alveolar nerve block is the main technique for anaesthesia of mandibular teeth.

- Alternative techniques:

o Intraligamentary anaesthesia: Injection into the periodontal ligament provides a limited and localised effect.

o Intrapulpar anaesthesia: Especially in endodontic treatments, it is effective in resistant pain after pulp tissue is opened.

o Intraosseous anaesthesia: It is provided by injection into the spongious bone through a small hole in the cortical bone.

- Topical anaesthesia: It is used to reduce pain in superficial soft tissues and to provide comfort before injection.

1.5. Clinical Indications and Application Areas

Local anaesthesia techniques are applied in all areas of dentistry (Pipa-Vallejo & García-Pola-Vallejo, 2004):

- Endodontics: Elimination of pulp vitality and painless working during root canal treatment.

- Periodontology: It is necessary in interventions such as flap operations, curettage, implant placement.

- Oral surgery: It is used in a wide range from tooth extractions to apical resections.

- Restorative and prosthetic dentistry: Increases patient comfort, especially in subgingival preparations and soft tissue manipulations.

Choosing the appropriate technique for each discipline directly affects the success of the procedure and the patient's approach to treatment.

1.6. Causes of Failure and Management

Anaesthesia failure is an important problem in clinical practice.

- Anatomical causes: Accessory nerves (e.g. mylohyoid), thick cortical structure and variations in the mandible.

- Infection: Acidic pH reduces the efficacy of the anaesthetic.

- Technical errors: Incorrect injection angle, insufficient needle depth, premature injection.

- Pharmacological factors: Inadequate dose of the administered agent, presence or absence of vasoconstrictors.

Alternative methods for management (intraligamentary, intrapulpar, intraosseous) can be applied, different agents can be used or the injection can be repeated.

1.7. Complications and Prevention Methods

Complications are classified as local and systemic:

- Local: Haematoma, nerve damage, needle breakage, trismus, infection. Mostly due to technical errors.

- Systemic: Toxicity, allergic reaction, syncope, cardiovascular side effects.

To prevent complications, aspiration should be performed, appropriate dose should be used, patient anamnesis should be taken carefully and the correct agent should be selected in risky patients. In addition, the physician should be familiar with emergency intervention protocols.

1.8. Current Approaches and Innovations

In recent years, local anaesthesia applications have been affected by technological developments.

- Ultrasound-guided anaesthesia: Direct visualisation of the nerves improves success in anatomical variations.

- Computer-controlled local anaesthesia devices (C-CLAD): Provides painless and safe administration by controlling the injection rate and pressure.

- New pharmacological agents: Studies on liposomal formulations and long-acting preparations are ongoing.

- Approaches to reduce pain perception: Virtual reality, distraction techniques and psychological preparation methods are used as supportive.

1.9. Conclusion and Clinical Recommendations

Local anaesthesia is the cornerstone of dental practice. In order to ensure clinical success, correct technique, appropriate agent selection and patient characteristics should be taken into consideration. Aspiration should be performed to prevent complications, dose calculations should be made meticulously and drug selection should be made carefully in individuals with systemic diseases (Daubländer, Müller, & Lipp, 1997).

Integration of current technologies and pharmacological developments into clinical practice will increase both patient comfort and treatment success. Therefore, it is important for clinicians to follow the literature in the field of local anaesthesia and constantly update their practices (Macfarlane, Gitman, Bornstein, El-Boghdadly, & Weinberg, 2021).

1.10. Local Anaesthesia in Special Patient Groups

1.10.1 Local Anaesthesia in Paediatric Patients

Local anaesthesia applications in children differ from adults due to pharmacokinetic and pharmacodynamic differences. Since the body surface area and circulatory volume of children are smaller, the mg/kg formula should be used in maximum dose calculations and adult doses should never be administered. In addition, psychological preparation and, if necessary, behavioural guidance techniques (tell-show-do) should be used before injection, as children may have high levels of anxiety. Infiltration anaesthesia is often sufficient in paediatric patients, even in the mandible, because the cortical bone is thinner than in adults (Blanton & Jeske, 2003).

1.10.2 Local Anaesthesia in Geriatric Patients

Metabolism and elimination of local anaesthetics may be slowed down in elderly individuals due to physiological decrease in liver and kidney function. In addition, polypharmacy is a condition that should be considered in terms of drug interactions. Therefore, low doses should be started and supplemented with additional doses if necessary. Vasoconstrictor preparations should be used with caution, especially in elderly patients with cardiovascular disease.

1.10.3 Local Anaesthesia in Pregnancy

Local anaesthesia in pregnancy should be carefully planned for maternal and fetal health. According to the FDA pregnancy category, lidocaine and prilocaine (Category B) are considered safe. There are limited data on the use of agents such as articaine and bupivacaine. Adrenaline-containing solutions can be used with caution at low concentrations, but overdosage should be avoided as they may have adverse effects on uterine blood flow. The second trimester is the most suitable period for dental procedures and local anaesthesia.

1.10.4 Local Anaesthesia in Systemic Diseases

- Cardiovascular diseases: Vasoconstrictors such as adrenaline may increase the risk of arrhythmias and hypertension in patients with serious cardiac problems. Therefore, vasoconstrictor-free agents or low concentrations should be preferred if possible.

- Diabetes: Local anaesthesia does not directly affect glycaemic control, but the presence of infection may reduce the success of anaesthesia.

- Liver and kidney diseases: Amide group agents are metabolised in the liver; therefore, the dose should be reduced in patients with severe hepatic impairment. Caution should be exercised in patients with renal impairment as the elimination of metabolites may be impaired.

- Allergic patients: Allergic reactions to ester group agents are more common. Allergy to amide group agents is rare, but testing and alternative options should be considered in patients with multidrug allergy.

1.11. Dose Calculations and Safety Limits in Local Anaesthesia

The safe use of local anaesthetics depends on accurate dose calculations. Since overdose can lead to systemic toxicity, every clinician should know the maximum doses and observe them in practice (Godzieba, Smektała, Jędrzejewski, & Sporniak-Tutak, 2014).

1.11.1 Dose Calculation Principles

Vücut ağırlığına göre: Maksimum dozlar genellikle mg/kg üzerinden hesaplanır.

- According to age and systemic status: Lower doses should be preferred in children, the elderly and individuals with systemic disease.

- According to the concentration administered: For example, 2% lidocaine solution contains 20 mg/ml. One cartridge (1.8 ml) contains approximately 36 mg lidocaine.

1.11.2 Maximum Safe Doses (approximate values)

- Lidocaine (adrenaline ile): 7 mg/kg, toplamda 500 mg'ı geçmemeli.

- Articaine: 7 mg/kg, maximum 500 mg.

- Mepivacaine: 6.6 mg/kg, maximum 400 mg.

- Prilokain: 8 mg/kg, maximum 600 mg.

- Bupivacaine: 2 mg/kg, maximum 90 mg.

Example: For a 70 kg healthy adult, a maximum of $7 \times 70 = 490$ mg can be used with lidocaine-adrenaline solution. This is approximately 13 cartridges (36 mg $\times$ 13 = 468 mg). However, in the clinic, it is generally recommended not to exceed 7-8 cartridges, leaving a safety margin.

1.11.3 Vasoconstrictor Limits

The limits of both local anaesthetic and vasoconstrictor should be considered in adrenaline added solutions (Pahade, Bajaj, Shirbhate, & John, 2023).

- In healthy individuals, the adrenaline limit is generally considered to be 0.2 mg (approximately 11 cartridges of 2% lidocaine + 1:100,000 adrenaline).

- The safe limit in individuals with cardiovascular disease is 0.04 mg (approximately 2 cartridges).

1.11.4 Clinical Recommendations

The lowest effective dose should always be used in dose calculations.

- In children, mg/kg calculation should be made strictly and "adult dose should not be reduced".

- Additional doses should be avoided in risky patient groups (pregnant women, elderly, cardiac patients) and vasoconstrictor-free agents should be preferred if possible.

- The total dose used during administration must be recorded and entered in the patient's file.

2.CONCLUSION

Local anaesthesia is one of the most important clinical procedures that form the basis of dental practice and directly affect patient comfort. Successful local anaesthesia can be achieved by choosing the right pharmacological agent, using the appropriate technique, considering patient characteristics and being prepared for possible complications. (Ghafoor et al., 2023).

While the amide group local anaesthetics used today increase clinical success with their high efficacy and safety profiles, technological innovations (ultrasound-guided applications, computer-controlled anaesthesia systems) and pharmacological developments (long-acting preparations, new formulations) make applications safer and more comfortable. However, clinicians need to have advanced anatomical knowledge, pharmacology and practical skills to prevent anaesthetic failures and minimise complications (Ho et al., 2021).

Local anaesthesia applications in special patient groups (paediatric, geriatric, pregnant women, individuals with systemic diseases) should be carefully planned, dose calculations should be made meticulously and safety limits should not be exceeded. This approach not only increases clinical success but also protects patient safety.

In conclusion, local anaesthesia techniques directly affect not only pain control but also the patient-physician relationship, treatment compliance and long-term clinical success in dental practice. Therefore, it is an integral requirement of modern dental practice that clinicians closely follow current developments, constantly update their practices in the light of scientific data and be prepared for possible complications.

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CHAPTER 2

Functional Appliances for Class II in Growing Patients: Diagnosis, Timing, and Outcomes

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Introduction

Class II malocclusion in the growing patient spans a spectrum of skeletal and dental patterns and remains one of the most common reasons for orthodontic consultation in childhood and adolescence (Di Blasio et al., 2021). Diagnosis should specify which elements are present: mandibular retrusion, maxillary excess (vertical and/or anteroposterior), dentoalveolar compensation, and vertical dysplasia.

Functional appliances-removable (e.g., Twin Block, Activator/Bionator, Frankel) and fixed (e.g., Herbst, Forsus/PowerScope, MARA)-aim to posture the mandible forward, rebalance perioral musculature, and guide eruption to reduce overjet and establish Class I canine/molar relationships. Consistent clinical effects include sagittal correction and overjet reduction; the skeletal response is typically modest and timing-dependent, while dentoalveolar contributions are substantial (Graber TM, Rakosi T, Petrovic AG., 1985). Functional therapy is best suited when mandibular retrusion predominates and meaningful growth remains, and it can be deployed as a stand-alone sagittal phase or integrated with comprehensive fixed or aligner finishing.

Practical success hinges on accurate phenotyping, growth staging, vertical control, incisor-torque management, and realistic expectations about compliance and retention. Calibrating these factors at the outset helps match appliance choice to the patient's pattern and supports predictable outcomes (Di Blasio et al., 2021; Graber TM, Rakosi T, Petrovic AG., 1985).

Diagnosis of Class II Malocclusion in the Growing Patient

Class II malocclusion in growing patients spans a wide spectrum, from essentially dentoalveolar problems on a near-normal jaw base to true skeletal discrepancies. A sound diagnosis therefore begins with phenotype: what is dental, what is skeletal, and how vertical and transverse patterns color the sagittal picture. Only then do cephalometric numbers add clarity to a pattern that is already visible in the face, the arches, and the occlusion.

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Dental versus Skeletal Class II

A dental Class II describes a molar/canine relationship that is distal to Class I on a roughly normal skeletal base. It most commonly arises when maxillary molars migrate mesially during transition (for example after premature loss of the maxillary second primary molars or with ectopic eruption of the first molars), or when interarch tooth-size discrepancies bias the occlusion-classically with small or missing maxillary lateral incisors or second premolars. Such cases may be unilateral or bilateral. Overjet need not be increased when incisors are not proclined; crowding and loss of arch perimeter in the maxilla are frequent accompaniments. Cephalometrically, ANB and Wits may be within normal limits; the deviant signal is limited to the dentoalveolar zone (upper incisor position and proclination; molar position/rotation), with normal maxillary and mandibular base positions relative to Nasion perpendicular and stable verticals (Fisk, Culbert, Grainger, Hemrend, & Moyers, 1953; Graber TM, Rakosi T, Petrovic AG., 1985).

A skeletal Class II reflects a jaw base disproportion and almost always carries natural dental compensation-upper incisors tending to retrocline and lower incisors to procline as the occlusion adapts to the basal discrepancy. In addition, the maxillary arch often appears narrowed transversely because it occludes against a more constricted segment of the mandibular arch; mesiolingual rotation of maxillary first molars is a common finding. On tracing, ANB and Wits are increased, while SNA and SNB trends depend on whether maxillary excess, mandibular deficiency, or both are present. Vertical parameters (SN-MP/FMA, lower anterior facial height) and appraisals to Nasion perpendicular help separate true skeletal displacement from dental protrusion or retroclination (Craig, 1951; Graber TM, Rakosi T, Petrovic AG., 1985).

Common Skeletal Subtypes

Mandibular deficiency-by size and/or position-is the archetypal Class II pattern. The profile is convex with a deep labiomental fold; the lower lip may be trapped behind proclined maxillary incisors in pronounced cases. Cephalometrics typically show increased ANB, reduced SNB, and often a clockwise mandibular rotation in patients with short rami/steep planes; in others the rami are normal or long, facial height short, and the mandibular plane flatter, with incisor inclinations masking the sagittal gap.

Vertical maxillary excess (VME) presents a characteristic esthetic profile with increased lower facial height, frequent anterior gingival display, and clockwise mandibular rotation. SNA may remain within normal limits, yet the vertical dimension dominates; the apparent skeletal Class II is secondary to downward-and-backward mandibular rotation. Cephalometric features include increased lower anterior facial height, a steeper mandibular plane, and inferior positioning of the maxillary molars-and, when an anterior component is present, of the maxillary incisors.

Maxillary anteroposterior excess (true midface prominence) must be separated from mere maxillary incisor protrusion. Here the entire midface-nose and infraorbital area included-projects forward, SNA is increased, and convexity is skeletal rather than purely dental. As in other skeletal Class II patterns, dentoalveolar compensation (mandibular incisor proclination, transverse maxillary constriction) may partly disguise the basal discrepancy at first glance.

Combination patterns are common. Many patients have mandibular retrusion together with maxillary excess-vertical, anteroposterior, or both-in varying degrees. Recognizing this mix helps plan vertical control and choose between growth modification and camouflage.

Cephalometric, Dental, and Transverse Appraisal

The cephalometric analysis should confirm what the clinical exam already suggests. Increased ANB and a positive Wits indicate a sagittal skeletal discrepancy. When cranial-base variation blurs angular measures, Nasion-perpendiculars to points A and B help distinguish maxillary prominence from mandibular retrusion. Vertical metrics such as SN-MP, FMA, and lower facial height clarify growth direction; together with molar verticals to the palatal plane, they separate true vertical maxillary excess from clockwise mandibular rotation due to posterior dental eruption. Dentally, the position of the upper incisors to NA/SN/Frankfort and the lower incisors to NB/MP shows the degree of compensation and signals the limits of camouflage. Transversely, mesiolingual molar rotation and arch-width discrepancies often reflect long-standing adaptation to a Class II base and may explain unilateral molar/canine relationships and midline shifts (Barbosa, Araujo, Behrents, & Buschang, 2017; Drelich, 1948).

Unilateral Class II

Because dental etiologies (mesial drift after early primary molar loss, ectopic eruption) are frequently asymmetric, unilateral Class II relationships are not rare. When coincident dental and facial midlines are present on a unilateral molar Class II, the problem is often dental; when the maxillary midline is deviated toward the Class II side, canine displacement or asymmetric space loss may be implicated. A careful space analysis-including the possibility of tooth-size discrepancies clarifies whether the asymmetry is dental, skeletal, or mixed.

Soft-tissue and Functional Context

Soft-tissue balance often mirrors the underlying skeletal story: convexity with upper lip prominence in maxillary excess, or lower-lip strain and deep labiomental fold in mandibular deficiency. Lower-lip entrapment behind proclined upper incisors both reflects and perpetuates overjet in Division 1 cases; in Division 2, retroclined maxillary incisors mask overjet yet deepen overbite. Observation of lip closure pattern, incisor display at rest and on smile, and tongue posture contributes to a treatment-oriented diagnosis without yet prescribing the mechanics (Saltaji, Flores-Mir, Major, & Youssef, 2012).

Phenotype in Growing Patients

In growing patients, phenotype predicts the path of correction. If mandibular retrusion is primary and growth remains, expect overjet and molar correction mainly through dentoalveolar change with a small skeletal contribution. When maxillary excess (vertical and/or anteroposterior) dominates, focus on vertical control and limiting maxillary displacement. Overall, growth-modifying methods yield modest skeletal effects and larger dental effects; timing near the pubertal spurt strengthens the skeletal signal but does not change the phenotype.

Records, Growth Assessment, and Timing

Baseline documentation should comprise standardized extra- and intraoral photographs, digital dental models obtained from scans, and panoramic and lateral cephalometric radiographs. Cone-beam CT is reserved for targeted indications-most often to investigate suspected condylar or craniofacial asymmetry or to screen the upper airway-and should not be used routinely. Assessment of growth status is integral to planning; the cervical vertebral maturation method provides a practical staging framework and can be supplemented by menarcheal history in girls and by serial standing-height measurements to track velocity.

With respect to timing, the most favorable skeletal response is typically observed around CVM stages 3-4, corresponding to the pubertal growth spurt (Baccetti, Franchi, & McNamara, 2005). Initiating treatment too early may prolong overall therapy without improving endpoints, whereas starting too late tends to shift the correction toward dentoalveolar change rather than skeletal adaptation. Notable exceptions include patients at heightened risk of incisor trauma due to excessive overjet and those with significant psychosocial concerns, in whom early overjet reduction may be justified even if ultimate outcomes resemble those of single-phase protocols begun later (Koroluk, Tulloch, & Phillips, 2003).

Treatment in Growing Class II

Headgear (extraoral). Extraoral traction applies a posterior–superior vector to the maxilla to restrain forward and downward displacement and to temper maxillary molar eruption. High-pull vectors are preferred when vertical control is a priority, with orthopedic protocols typically using heavier intermittent forces worn evenings and overnight. Force application through or slightly above the molar center of resistance helps limit tipping; by contrast, predominantly cervical pull tends to extrude maxillary molars and may provoke clockwise mandibular rotation in hyperdivergent patients (Tüfekçi, Allen, Best, & Lindauer, 2016).

Functional appliances (intraoral). Appliances that posture the mandible forward modify neuromuscular patterns and guide eruption, yielding a consistent dentoalveolar response and, in well-timed cases, a modest skeletal effect. They are most appropriate when mandibular retrusion is the principal driver and meaningful growth remains. Vertical outcomes depend on appliance design and bite-block strategy, and incisor torque control should be anticipated in the finishing phase (Franchi, Pavoni, Faltin Jr, McNamara Jr, & Cozza, 2013).

Interarch traction (Class II elastics). Elastics primarily achieve dental correction by mesializing the mandibular dentition and, secondarily, retracting maxillary anterior teeth. Their vertical side effects-extrusion of lower molars and upper incisors can steepen the occlusal plane and increase lower facial height, so they are best suited to dental Class II patterns or as a finishing adjunct in mild skeletal discrepancies rather than as a primary tool in the early mixed dentition.

Camouflage and orthognathic surgery. As growth wanes, management shifts toward dental camouflage or surgical correction. Camouflage-often involving extractions and careful anchorage-can harmonize the occlusion and profile in mild-to-moderate skeletal Class II if incisor positions and soft-tissue goals allow. More pronounced skeletal disharmony, unfavorable incisor inclinations, or esthetic constraints point to orthognathic approaches once growth is complete (Tucker, 1995).

Functional Appliances: Overview and Selection

Functional therapy encompasses removable tooth-borne designs, fixed tooth-borne systems, and newer aligner-based mandibular advancement modules. Selection is guided less by brand and more by phenotype, growth stage, vertical tendencies, anticipated cooperation, hygiene/esthetic priorities, and the need to combine sagittal correction with comprehensive alignment. Across all formats, clinicians should expect a reliable dentoalveolar response and a variable, timing-dependent skeletal component; lower incisor torque and vertical expression are the recurring management theme (Cozza, Baccetti, Franchi, Toffol, & McNamara, 2006).

Removable Tooth-borne Appliances

Among removable options, the Twin Block is the most widely used contemporary design (Figure 1). Its paired acrylic plates incorporate inclined planes (commonly around 70°) that posture the mandible forward while allowing patients to function, speak, and often even eat with the appliance in place (Clark, 1988). Because the occlusal blocks can be adjusted, the Twin Block offers practical control over vertical expression and lends itself to stepwise mandibular advancement. The principal trade-off is a tendency toward lower incisor proclination if torque is not anticipated in the overall plan (C. M. Mills & McCulloch, 1998).

Figure 1 Twin Block Appliance

Classic monobloc appliances-the Activator and its lighter Bionator variant achieve similar sagittal aims with different handling qualities. The Activator's bulk confers sturdiness and neuromuscular deprogramming but demands more adaptation for speech; the Bionator reduces acrylic volume while preserving guidance of eruption and mandibular posture. Both can be configured with capping, labial bows, or expansion screws when arch form or incisor position requires adjunctive control (Basciftci, Uysal, Büyükerkmen, & Sari, 2003).

The Frankel FR-2 occupies a distinct niche as a largely tissue-borne appliance. Vestibular shields and lip pads are used to alter perioral muscle balance, encourage transverse development of the dental arches, and reduce soft-tissue pressures that perpetuate malocclusion. FR-2 is technique-sensitive and more fragile than plate-based designs, yet many patients find its daytime wear profile acceptable once accustomed to the soft-tissue components (Fränkel, 1969).

Fixed tooth-borne appliances

Fixed functional appliances are preferred when cooperation is uncertain or when sagittal correction must proceed alongside fixed-appliance alignment. The

Herbst appliance, with its rigid telescopic mechanism carried on bands or splints, maintains continuous mandibular advancement independent of patient effort and is a dependable tool for overjet and molar-relation correction. Its characteristic side effect is proclination of the lower incisors unless robust torque control is integrated into the archwire sequence; soft-tissue irritation around hardware and screw loosening are familiar but manageable nuisances. Splint-supported variants can assist vertical moderation in high-angle faces (Pancherz, 1985).

Push-rod/coil systems such as Forsus, PowerScope, and Jasper attach directly to fixed appliances, delivering relatively constant forces while alignment continues (Jasper & McNamara, 1995; Paulose et al., 2016; Vogt, 2006). They are well suited to mid-treatment introduction, provide predictable dental effects with some skeletal contribution near the growth spurt, and share the lower-incisor torque considerations of other fixed functionals, typically with a lighter emergency burden than rigid telescopes. MARA, a crown- or band-supported system that uses shims to hold the mandible forward, serves as a practical alternative when Herbst is not ideal; its occlusal support and modular advancement appeal in cases where simplicity and durability are priorities (Eckhart & White, 2003).

Aligner-based mandibular advancement

Aligner systems with integrated mandibular-advancement wings extend functional therapy to patients prioritizing esthetics and hygiene, particularly in the late mixed or early permanent dentitions with mild-to-moderate Class II due to mandibular retrusion. These modules combine staged advancement with digital tooth movement planning, allowing simultaneous alignment and sagittal correction when cooperation is strong. The literature base is growing; early clinical experience points to familiar dentoalveolar signatures, occasional posterior open-bite tendencies during transition phases, and the same need for thoughtful vertical and torque control during finishing (Wu et al., 2023).

Mechanisms and Expected Effects

Primary actions

Functional correction works through three intertwined processes. First, mandibular advancement alters the neuromuscular environment: forward positioning reduces lower-lip entrapment, changes the vector of perioral and masticatory muscles, and establishes new patterns of occlusal contact. Second, a characteristic dentoalveolar response follows. Maxillary incisors tend to retrocline while mandibular incisors proclinate; maxillary posterior eruption is usually restrained and mandibular posterior eruption encouraged-a “differential eruption” that helps normalize the sagittal relationship and settle the bite. Third, a skeletal signal is present but modest and variable. Many patients show some restraint of maxillary forward displacement (a headgear-like effect) and signs of mandibular adaptation at the condyle and glenoid fossa. The magnitude of these skeletal changes improves when treatment coincides with the pubertal growth spurt, yet inter-patient variability remains considerable, and the average correction still relies heavily on dentoalveolar change (Lee W. Graber, Katherine W. L. Vig, Greg J. Huang, Pádhraig S. Fleming, 2022).

Vertical control

The vertical expression of functional therapy is governed largely by appliance design. Occlusal bite blocks can be contoured to direct eruption: trimming posterior acrylic encourages molar eruption and is advantageous in deep-bite patterns, whereas maintaining flat posterior surfaces helps limit posterior eruption in hyperdivergent or open-bite tendencies. Splint-supported Herbst variants offer additional moderation of posterior extrusion in high-angle faces. In selected cases where maxillary vertical excess contributes to the problem, a high-pull extraoral vector can be combined with intraoral advancement to reinforce vertical control without adding unwanted molar extrusion.

Managing Incisor Torque

Because lower incisor proclination is a common trade-off of functional correction, torque management should be anticipated from the outset (Cozza et al., 2006). In fixed-functional sequences, rectangular stainless-steel archwires with appropriate lower-incisor torque and cinch-backs reduce the tendency for forward tipping; a passive lower lingual arch may be considered when periodontal phenotype and hygiene permit. With removable appliances such as the Twin Block, lower incisor capping or judicious labial-bow adjustments can temper proclination while sagittal correction proceeds. Aligner protocols address the same issue digitally by programming counter-torque and staging movements to preserve axial control as the mandible is advanced.

Evidence and Ongoing Controversies

Animal studies supported condylar cartilage responsiveness to forward posturing; human clinical studies show reliable overjet/molar correction with variable skeletal gains and prominent dental effects (Baume & Derichsweiler, 1961). Prospective controlled trials comparing removable functionals and headgear report similar overall sagittal improvements with different dental signatures; inter-patient variability is high, and the timing, magnitude, and durability of true skeletal change remain debated (Keeling et al., 1998; McNamara, Bookstein, & Shaughnessy, 1985; J. R. E. Mills, 1991).

Predictors, Side Effects, and Risks

Treatment response in growing Class II patients is not uniform, and several clinical features consistently forecast a smoother course. The most favorable outcomes are seen when therapy begins around the pubertal growth spurt (CVM stages 3-4), particularly in patients whose phenotype is dominated by mandibular retrusion rather than maxillary excess (Baccetti et al., 2005). A moderate overjet-typically in the range of 6-9 mm provides room for sagittal correction without forcing extreme dental compensation, while a neutral or low mandibular plane angle simplifies vertical control. Cooperation remains a powerful determinant regardless of appliance choice; even with compliance-light fixed functionals, attentive hygiene and appointment adherence translate into fewer interruptions and steadier progress.

Conversely, several findings should temper expectations or prompt modification of the plan. When little growth remains, the skeletal contribution to change is small and correction relies heavily on dentoalveolar effects. Severe vertical maxillary excess or open-bite tendencies, if not actively managed, can convert sagittal efforts into unwanted vertical extrusion and clockwise mandibular rotation. A thin gingival phenotype combined with crowding increases the risk that lower incisor proclination will encroach upon the periodontal envelope; meticulous torque control and, in some cases, staging of alignment become essential. Poor oral hygiene is a practical red flag in any appliance system, as it raises the risk of white-spot lesions and caries and can force pauses that erode the timing advantages of growth-modifying care.

The side-effect profile of Class II correction is well characterized and, with forethought, manageable. Lower incisor proclination is the most common trade-off of functional mechanics; pre-emptive torque control with rectangular stainless-steel archwires, judicious negative torque, and cinch-backs reduces forward tipping, and a passive lower lingual arch may be considered when periodontal tissues and hygiene permit (C. M. Mills & McCulloch, 1998). Upper incisor retroclination and a tendency to deepen the curve of Spee can be countered by planning maxillary torque and leveling early; bite turbos or occlusal build-ups are useful when interferences threaten anterior control. A transient posterior open bite is not unusual after appliance removal and typically resolves with brief finishing elastics as intercuspation matures. Soft-tissue irritation and minor hardware issues are part of routine care: smoothing and polishing, strategic use of wax, and ready access to spare components keep these events from derailing progress. Finally, the risk of white-spot lesions and caries is minimized by a preventive program that pairs fluoride varnish or gel with dietary counseling and short-interval reviews-an approach that protects outcomes as effectively as any mechanical adjustment.

Phase II Finishing and Retention

Finishing

Once the sagittal relationship has been normalized, treatment shifts to the quiet work of detailing. The objectives are stable intercuspation, coordinated arch forms, and harmonious incisor display framed by balanced torque and gingival margins. Finishing sequences focus first on establishing and maintaining canine guidance (or appropriate premolar group function when canine morphology dictates), leveling any residual curve of Spee, and refining root angulations to optimize contact lengths and papillary fill. Where triangular crowns or prior crowding predispose to "black triangles," small, well-planned interproximal enamel reductions paired with root convergence help improve embrasure form while preserving periodontal health. Smile esthetics-incisal edge curvature relative to the lower lip, display at rest and on smile, and midline coincidence-are reviewed as part of the final torque and vertical adjustments.

Adjunctive interarch mechanics are used sparingly and with intent. Short Class II elastics can help preserve canine and molar relationships during detailing, provided the vertical pattern permits; in hyperdivergent faces or when anterior bite opening is a concern, lighter vertical elastics or occlusal build-ups may be preferable to avoid steepening the occlusal plane. Transient posterior open bites that appear after removal of functional bite-blocks typically settle with light settling elastics and time. Occlusal equilibration is reserved for minor balancing interferences once the orthodontic finishing is complete and stable (Morton & Pancherz, 2009).

Retention

Retention consolidates the occlusion achieved during active therapy and guards against the re-expression of growth and soft-tissue habits. A bonded canine-to-canine retainer in the mandible remains a reliable baseline in most cases, offering continuous control of the segment most susceptible to late crowding. In the maxilla, a vacuum-formed retainer is commonly chosen for its ability to preserve anterior torque and transverse width; a Hawley design remains useful when controlled posterior settling is desired or when small midline or molar rotations must continue to be guided. Selection is individualized to periodontal phenotype, oral hygiene, and patient preferences, and should be accompanied by clear wear and maintenance instructions (Littlewood, Kandasamy, & Huang, n.d.).

Duration is best framed as long-term stewardship rather than a fixed interval. Adolescents continue to grow into early adulthood, and late mandibular changes can modestly alter overbite/overjet and anterior alignment even after excellent finishing. Families should be counselled that night-time wear of the maxillary retainer is an ongoing habit, and that the bonded mandibular retainer requires routine monitoring and prompt repair if detached. In patients with a perceived tendency toward sagittal relapse-particularly after pronounced overjet reduction-a period of night-time wear with the previous functional device or a maxillary retainer configured to reinforce sagittal control can be helpful. Regular post-debond reviews focus on retainer integrity, hygiene around bonded wires, and stability of the occlusion as growth completes.

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CHAPTER 3

Periodontally Accelerated Osteogenic Orthodontics (PAOO) and Piezocision

Ferit Dadaşlı[1]

Introduction

Surgically facilitated orthodontics has moved from block-osteotomy concepts to biologically driven strategies that transiently reprogram alveolar bone turnover (Generson, Porter, Zell, & Stratigos, 1978). Periodontally Accelerated Osteogenic Orthodontics (PAOO uses selective alveolar decortication plus grafting (M. T. Wilcko, Wilcko, Pulver, Bissada, & Bouquot, 2009). By contrast, piezocision is a minimally invasive approach (Dibart, 2011). Both aim to harness the regional acceleratory phenomenon (RAP), a short-lived burst of bone demineralization and remodeling after surgical insult that reduces tissue resistance to tooth movement and may expand the "alveolar envelope" within which orthodontics operates. This chapter synthesizes historical development, biologic principles, diagnosis and case selection, techniques, outcomes and complications.

History

Surgically assisted tooth movement predates modern orthodontics. Early corticotomy and osteotomy protocols conceptualized movement of dentoalveolar "bony blocks," culminating in Köle's 1959 description of vertical interproximal corticotomies connected by a subapical osteotomy to create mobilized segments (Köle, 1959). Subsequent animal work refined safety boundaries for vascularity and pulpal health while discouraging marginal crestal involvement (Düker, 1975). At the turn of the 21st century, Wilcko et al. proposed that the post-decortication speed-up comes from a transient demineralization–remineralization cascade, not block transport. They also formalized a technique combining selective decortication with alveolar augmentation (W. M. Wilcko, Wilcko, Bouquot, & Ferguson, 2001).

Minimally invasive variants followed. Park introduced corticision, a flapless, transmucosal cortical incision with a reinforced scalpel and mallet that recruits a RAP response without raising a flap (Park, 2015). Dibart and co-workers then described piezocision, a flapless series of tiny buccal incisions with ultrasonic cortical micro-osteotomies, optionally combined with subperiosteal tunneling to place grafts in selected segments (Dibart, 2011). Both techniques sought to reduce morbidity while retaining biologic benefits. Narrative overviews in

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major orthodontic journals echo these developments and set the comparative stage for PAOO and piezocision (Amit, Jps, Pankaj, Suchinder, & Parul, 2012; Wu, Wang, & Zhou, 2021; Yener Ozat, Ruhi Nalçacı, 2013).

Biology

Regional acceleratory phenomenon (RAP)

Frost described the regional acceleratory phenomenon as a localized, injury-triggered surge in hard and soft-tissue turnover that expedites healing 2-10 fold, and temporarily lowers mineral density (osteopenia) (Frost, 1983). In the alveolus, RAP begins within days, peaks around 1-2 months, persists for ~4 months, and gradually subsides by 6-24 months, although continued tooth movement can prolong its expression.

Corticotomy increases osteoclastic resorption on the pressure side and osteoblastic apposition on the tension side. Cancellous bone shows faster turnover. At the molecular level, micro-injury alters blood flow and oxygen tension, upregulating angiogenic factors (e.g., VEGF) and pro-inflammatory cytokines. The RANKL/M-CSF/OPG balance shifts to favor osteoclastogenesis and remodeling (Wu et al., 2021).

Modeling and Remodeling

PAOO's key addition-particulate bone grafting over decorticated cortices-aims to harness RAP while adding net bone volume. Augmenting a thin facial plate can widen the alveolar envelope, help repair existing dehiscences, and lower the risk of new ones during tooth movement (Wu et al., 2021).

In the long term, remineralization densifies the osteoid matrix. If the graft integrates, facial thickness may remain above baseline, which can support long-term stability in thin biotypess (Amit et al., 2012; Wu et al., 2021).

PAOO and Piezocision: Biology

PAOO uses full-thickness flaps, wider decortication, and routine particulate grafting. The greater injury can trigger a stronger, longer RAP and if the graft integrates and maintains its volume, cortical plate thickness increases. On the other hand, piezocision relies on micro-incisions and ultrasonic corticotomies. This typically provokes a local RAP, but without tunneling and grafting it seldom changes alveolar anatomy beyond short-term demineralization. Reviews support this view and also note lower morbidity with piezocision (Charavet, Charpenay, Kernitsky, & Dibart, 2024).

Diagnosis and Case Selection

Interdisciplinary assessment

PAOO and piezocision are inherently interdisciplinary. The orthodontist plans tooth movement, anchorage, and forces on a shortened timeline. The periodontist evaluates soft-tissue phenotype and keratinized width, checks for dehiscence/fenestration and site-specific risks, and plans incisions, decortication, and any needed augmentation. Reviews support this collaboration because risks and benefits span bone, teeth, and gingiva-not a single tissue. (Amit et al., 2012; Yener Ozat, Ruhi Nalçacı, 2013).

Clinical and Radiographic Evaluation

Clinical examination focuses on periodontal health, mobility, phenotype, and mucogingival concerns. Cone-beam CT is often used to visualize cortical thickness, root proximity, and defects-especially in anterior segments where labial plates are thin. Although definitive CBCT algorithms are not standardized, the rationale for imaging aligns with the objective of respecting or expanding the alveolar envelope. (Yener Ozat, Ruhi Nalçacı, 2013).

Patient Factors

Age alone does not preclude accelerated approaches, but adults, who desire shorter treatment-also more often present with thin labial plates and recession. Systemic modifiers of bone metabolism, smoking, and poorly controlled systemic disease are relative or absolute contraindications; poor oral hygiene and active periodontal disease are universal exclusions (Kamal, Malik, Fida, & Sukhia, 2019; Yener Ozat, Ruhi Nalçacı, 2013). Aesthetic priorities may shape the choice between full-flap PAOO (more swelling, potential ecchymosis, and sutures) and piezocision (punctate scars and quicker recovery).

Indications and Contraindications

Across reviews and case series, common indications include (a) arch development for moderate–severe crowding, often with fewer extractions, (b) augmentation-assisted decompensation in thin anterior plates, (c) accelerated canine retraction and en-masse retraction, (d) facilitation of impacted canine eruption, and (e) adjunctive expansion in mild to moderate transverse deficiencies. Contraindications include active periodontitis, very thin soft-tissue biotype with existing recession (without concomitant soft-tissue grafting), severe posterior cross-bite better managed by surgically assisted expansion, and cases whose skeletal or smile esthetic problems are better served by osteotomy (e.g., bimaxillary protrusion with excessive gingival display) (Amit et al., 2012; Yener Ozat, Ruhi Nalçacı, 2013).

Techniques Overview

PAOO

Most PAOO protocols reflect the Wilcko approach: full-thickness flaps are reflected to expose buccal and lingual cortical plates; decortications-interdental verticals often connected by a subapical corticotomy-are performed shallowly to scar the cortex without segment mobilization; and particulate grafts are applied over the activated cortices before flap closure. Typical graft types include deproteinized bovine bone, decalcified freeze-dried bone allograft, and autogenous combinations; barrier membranes are generally discouraged, and there is no high-level evidence favoring one graft over another (Amit et al., 2012; W. M. Wilcko et al., 2001).

Soft-tissue management favors flap designs that ensure coverage and blood supply while preserving the interdental papillae; meticulous primary closure without tension is emphasized. Short-term steroids, antibiotics, and analgesics may be prescribed; long-term non-steroidal anti-inflammatory drugs are avoided to prevent interference with RAP. Patients commonly experience edema, ecchymosis, and moderate pain-typically self-limiting (Amit et al., 2012).

Force application is usually initiated one week before to within two weeks after surgery, to capitalize on the 4-6 month acceleratory window; archwires are advanced more quickly than in conventional treatment (Anand K. & Maan, 2018).

Piezocision

Piezocision uses short buccal vertical micro-incisions placed interproximally in attached gingiva. An ultrasonic (piezoelectric) knife is inserted through each incision to create cortical micro-osteotomies of controlled depth, sometimes followed by subperiosteal tunneling if bone or soft-tissue grafting is planned. Early human and animal studies show accelerated movement with lower morbidity, while later overviews emphasize its favorable acceptance profile and the option of limited grafting (Dibart, 2011).

Appliances and Activation

Fixed appliances and clear aligners can both be integrated with PAOO/piezocision, provided that activation cadence is compressed to match the biologic window. Reviews suggest starting with stiffer initial wires than usual in PAOO cases and shortening revisit intervals to approximately two weeks during the peak RAP phase; in aligner therapy, this translates to more rapid aligner changes under close periodontal monitoring. The window typically lasts

4-6 months, after which finishing proceeds at conventional speed (Dibart, Keser, & Nelson, 2020; Sultana, Ab Rahman, Zainuddin, & Ahmad, 2022).

Anchorage and Biomechanics

Because resistance is reduced selectively in activated segments, differential anchorage opportunities exist: segments without corticotomies may behave as higher-resistance units. Temporary anchorage devices (TADs) integrate well with PAOO and are frequently reported in canine retraction and molar intrusion under accelerated conditions, offering force control while resisting reciprocal effects. Light, continuous forces remain prudent, as peak biological responsiveness may magnify side effects from heavy forces.

Outcomes

Treatment Duration

Across observational reports and reviews, PAOO is associated with substantial reductions in overall treatment time-often reported as one-third to one-quarter of conventional duration-especially for alignment and extraction space closure (Wu et al., 2021). In extraction cases, controlled trials show shorter retraction phases with corticotomy assistance (Wang, Mei, Han, Luan, & Zhou, 2022). PAOO has been reported to shorten treatment about 3-4 fold, with complex cases averaging ~6 months instead of ~18-27 months, and severe cases commonly finishing in 6-8 months (Ferguson, Wilcko, Wilcko, & Makki, 2015). Piezocision studies also report faster alignment, though pooled estimates vary and protocols are heterogeneous (Sultana et al., 2022).

Periodontal Outcomes

A 2019 systematic review and meta-analysis of randomized trials comparing PAOO variants reported significant improvements in periodontal health at treated sites and shorter treatment durations, while finding no significant differences in probing depths, bone density, or root length between bioactive-glass–augmented corticotomy and corticotomy alone within the small number of trials available (Kamal et al., 2019).

Dental Outcomes

Shorter force application time is hypothesized to reduce cumulative root resorption. Clinical and animal studies cited in the PAOO literature report no increase in resorption risk with corticotomy-assisted movement; pulp vitality is generally preserved (Zhou et al., 2024). Systematic reviews to date have not demonstrated excess root shortening with PAOO relative to controls, albeit with small samples and variable imaging methods (Kamal et al., 2019).

Comparison of PAOO and Piezocision

- Indications: PAOO is advantageous when both speed and alveolar augmentation are desired (thin phenotype, planned decompensation with labial torque). Piezocision fits when acceleration is needed with minimal morbidity and no major need to thicken plates.
- Efficacy: Both accelerate movement; only PAOO predictably increases cortical thickness (when grafting is effective).
- Morbidity & cost: PAOO is costlier and more invasive; piezocision has quicker recovery and lower morbidity.
- Learning curve: Flap handling and augmentation make PAOO more technique-sensitive; piezocision demands precise radiographic root mapping and depth control.
- Stability: Reports suggest improved stability when alveolar augmentation increases bony support; flapless methods are not expected to enhance stability via anatomy change, although reduced relapse is sometimes observed anecdotally due to fiber disruption and rapid correction (Amit et al., 2012; Wu et al., 2021).

Risks and Complications

Intraoperative and early postoperative risks include edema, ecchymosis, and pain-usually self-limited. Hematomas can follow intensive corticotomies; infection is uncommon with asepsis and appropriate antibiotics. Flap dehiscence or graft exposure is more likely with thin tissues, tensioned closures, or marginal incisions placed too close to the crest. Transient paresthesia is rare with shallow decortications but underscores the need to respect root proximity and neurovascular anatomy (Wu et al., 2021).

In the long term, recession and black triangles remain concerns in thin biotypes regardless of technique and may be reduced with pre-emptive soft-tissue grafting when indicated. Over-aggressive or misplaced cortical cuts risk root damage, and inaccurate tunneling risks incomplete graft containment and resorption. Existing literature reports preserved pulpal vitality and no consistent increase in root resorption compared with conventional treatment, though long-term, high-quality data are limited (Amit et al., 2012; Ozat & Nalcaci, 2013).

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