INTERNATIONAL STUDIES IN DENTISTRY

EDITOR
ASSOC. PROF. DR. VOLKAN ARIKAN

March 2024

SERÜVEN YAYINEVİ

Genel Yayın Yönetmeni / Editor in Chief • C. Cansın Selin Temana

Kapak & İç Tasarım / Cover & Interior Design • Serüven Yayınevi

Birinci Basım / First Edition • © Mart 2024

ISBN • 978-625-6644-85-4

Serüven Yayınevi / Serüven Publishing
Türkiye Adres / Turkey Address: Kızılay Mah. Fevzi Çakmak 1. Sokak
Ümit Apt No: 22/A Çankaya/ANKARA
Telefon / Phone: 05437675765
web: www.seruvenyayinevi.com
e-mail: seruvenyayinevi@gmail.com

Baskı & Cilt / Printing & Volume
Sertifika / Certificate No: 47083

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CONTENTS

CHAPTER 1

ASSESSMENT OF THE MECHANICAL METHODS EMPLOYED IN INCISOR INTRUSION DURING ORTHODONTIC TREATMENT- A NARRATIVE LITERATURE REVIEW

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The field of orthodontics has experienced notable progress in technology and treatment approaches, particularly in the area of incisor intrusion. This procedure is essential for treating severe deepbites, minimizing excessive gum exposure (gummy smile), and enhancing overall dental appearance and functionality. The process of incisor intrusion is facilitated by an intricate interaction of forces that are specifically aimed at vertically shifting the teeth into the jawbone. This section examines the orthodontic techniques widely used to intrusion of incisors, such as classic fixed appliances, temporary anchoring devices (TADs), and clear aligner technology.

A. **Mechanics Used in the Intrusion of Incisors**

The mechanics of intrusion can be classified into two primary categories: continuous arcs and segmental arcs [1]. Continuous arches work on the principle of action-response, so while they intrude the incisors, they also cause some extrusion of the posterior teeth used as support. Continuous arches provide incisor intrusion and molar extrusion at the same time. Continuous arches are more suited for treating deep bite cases with a normal growth pattern and an increased Spee curve, whereas segmental arches are suggested for instances that specifically require incisor intrusion. Incisor intrusion can be achieved by type back bending on molars. Wire thickness, material, method of attachment to the brackets and torque are different. But all methods use continuous and light forces [1,2] (Table 1).

1. **Edgewise Technique**
2. **Begg Technique**
3. **Segmental Intrusion Arch**
4. **Continuous Intrusion Arch**
5. **'2x4 Arch' Mechanics**
6. **Utility Arches**
7. **Connecticut Intrusion Arch (CTA)**
8. **J Hooked Headgear**
9. **Orthodontic Mini-Screws**
10. **Clear Aligners**

Table 1. Demonstration of mechanics used in intrusion of incisors.

1. **Edgewise Technique**

In the Edgewise technique, treatment begins with the leveling of the teeth using a thin round archwire. The continuity of this wire allows correction of the deep speee curve at the initial stage. In this technique, the correction of the deep overbite is done with the help of second-order bends (type back bend) applied to the molars. With these bends, the molars are tilted backwards while the incisors are intruded. At the same time, to correct the deep bite, the Edgewis technique uses step bends (step-down bends for the lower, step-up bends for the upper), class II elastics and cervical headgear applied to the incisors [3].

With the use of reverse spee bending, curved or straight archwires, uprighting of the lower molars, extrusion of the lower premolars and a forward inclination of the lower incisors occur, which helps to resolve the deep bite [3,4].

2. **Begg Technique**

In this technique; anchoring bends are formed on the 0.016" Australian archwire 3 mm mesial to the 1st permanent molar tubes. The main advantage of this technique is the effective opening of the bite by extrusion of the lower molars and distal tilting of the upper molars [5,6].

3. **Segmental Intrusion Arch**

This technique was described by Charles Burstone in the 1950s. The principle of this treatment is to establish a more precise and predictable force system by dividing the dental arch into anterior and posterior segments and using wires of different thickness. Therefore, the use of only incisor intrusion movement allows for an outcome that cannot be attained with typical segmental arch treatment [7].

In 1977, Burstone described the intrusion mechanics consisting of three parts:

1. Posterior anchorage unit
2. Anterior segment
3. Intrusive arch ring [7]

In the first stage of treatment, the posterior teeth are leveled and the buccal segment is stabilized. A transpalatal arch is used to increase anchorage in the upper jaw and a lingual arch in the lower jaw. To increase the stability of the posterior segments, 0.018-0.025 inch or 0.021-0.025 inch wires are used after leveling. The intrusion arch is twisted from 0.018-0.022 or 0.018-0.025 inch arch wire. The helix should be 3 mm in diameter, wrapped 2.5 times, and rest against the mesial of the auxiliary tube. The archwire passes through the gingivae of the incisors and when attached to the anterior teeth, intrusive force is generated. The length of the wire, activated by the helix, is shortened, so that the incisors are not proclinated at the same time at the end of the intrusion. The wire is not directly attached to the incisors; the anterior segment can be attached to the central teeth or the four incisors labially, incisally or gingivally [8–11] (Figure 1).

Figure 1. Application of a segmental intrusion arc to the lower jaw.

4. **Continuous Intrusion Arch**

The continuous intrusion arc is stranded from angled TMA wire or stainless steel wire. If TMA wire is preferred, no helix is required. This arc is bent from 0.016 x 0.022 inch TMA, 0.017 x 0.025 inch TMA or 0.018 x 0.025 inch stainless steel wire with 2.5 helix. To avoid a tip back effect on the molars, a Spee (V) bend is made in the first premolar region of the arch. This arch is applied according to the targeted movement. For example: if the incisors are to be advanced with the intrusion of the incisors, the arch is connected at the midline of the central teeth. If translative intrusion of the incisors is desired, the force must pass through the center of resistance of the incisors. In this case, the arch should be connected from the distal parts of the lateral brackets. If forward movement of the incisors is not desired, the "cinch back" or "tieback" should be bent [12–16] (Figure 2).

Figure 2. Application of a continuous intrusion arc to the lower jaw.

5. '2x4 Arch' Mechanics

This mechanics includes 2 molars in the posterior region and 4 incisors in the anterior region. These arches can be activated in various ways and provide a wide range of force application. The most important feature of these arches is the application of different forces and moments to the teeth by making "V" bends on them. The location and amount of "V" bends, whether the archwire is round or angular, how and from which point it is connected to the brackets determine how the system will work. The best examples of "2x4 arch mechanics" are straight arches with tip backs (or Spee bends) or Ricketts' utility arches [17]. These arches are often used in mixed dentition, where permanent premolars and canines are not included posteriorly. When a 'V' bend is made on a 2x4 arch, the anterior region of the arch extends to the vestubular sulcus. When the wire is attached to the incisors, a force system is created that involves both the incisors and the molars. The "V" bend creates a negative moment on the molars [17].

When intrusion of the incisors is aimed, the "V" bend is made at the first primary molar alignment. If this bend is made closer to the molar, the effect of distal tipping of the molars is minimized [18].

If the molars are cinch back on the arch, the molars try to go distally and the incisors mesially. In such a case, because of the greater anchorage of the molar, the incisors do not procline and protrude, and their roots tilt palatally. If the angle of the type back bend in the molar and the angle of entry of the incisor are equal, the molars are bent distally and the incisors are bent mesially. If the angle in the wire is increased on the side of the molar, it results in intrusive movements in the incisors and extrusive movements in the molars. If the torque angle is greater than the molar type back angle, it creates moments in opposite directions and with different severity, and there is elongation of the incisors rather than intrusion and the bite deepens [17–19].

6. Utility Arches and Bioprogressive Treatment

Bioprogressive technique is not only a treatment method, but a new philosophy presented by Dr. Ricketts. His philosophy includes the concept of controlled root and torque movements at every stage of treatment, controlled muscular and cortical bone anchorage, and overtreatment for long-term stability. In the bioprogressive technique, the use of a utility arch for incisor intrusion has been proposed. This arch is similar in design to the passive utility arch, but the arch is activated to intrude the teeth.

Utility arch consists of 5 basic parts: a) Anterior region b) Anterior step c) Buccal bridge d) Posterior step e) Posterior region

Utility arches are among the 2×4 arch mechanics. The utility arch was originally developed to flatten the Spee curve in the mandible, but it has been adapted to fulfill more functions than lower incisor intrusion. It acts as a passive utility arch stabilizer or placeholder. It is ideal during mixed dentition when it allows the eruption of canines and premolars.The utility arch used for intrusion is designed similarly to the passive arch, but is activated to intrude the lower anterior teeth. When activated, it produces approximately 25 g of force on each of the lower incisors, this level of force is considered ideal for the intrusion of the lower teeth.In this technique, the arches are segmented and the posterior segment is used to anchor the molars, while the anterior segment contains the incisors.Anteriorly, the arch is directly connected to the incisor brackets. The utility arch bypasses the canine and premolar teeth. There is another very important reason for this design besides its use in mixed dentition. Very low forces are required for the intrusion movement. Especially in the lower incisors, even 40 g of force can be effective. For this, the length of the wire has been increased, thus reducing the force transmission. The front step of the arch is usually bent by 5-8mm and the back step by 3-4mm [20,21].

When activated, the anterior segment moves towards the gingivale, and when the incisors are placed in their brackets, an intrusion force is generated. At the same time, extrusive movement of the posterior segment occurs as a reaction. Two main side effects should be expected from intrusive mechanics. One is incisor inclination and the other is molar extrusion. Due to the moment created by the force pair, the molar root tends to move mesially. At the same time, since the extrusion force acts on the buccal side of the molar where the bracket is located, this causes the molar to tilt lingually.

This technique emphasizes the control of root movements compared to treatment methods using round and thin wires, which provide more free tooth movements. For cortical anchorage, the roots are placed against the cortical bone. Once activated, a light and continuous force is transmitted from the molars to the incisors by the long arm [15].

According to Profitt, if there is a free ending of the arch during intrusion, labial bending of the incisors will occur. Since the force is applied labial to the center of resistance of the 4 incisors, these teeth will try to be proclinal. When the utility arch is actively placed in the brackets of the incisors, labial crown torque will occur because the direction of the angled wire will change direction inside the bracket. To prevent this, the wire can be given a lingual crown torque or cinched back. It is recommended to correct the deep bite at the beginning of treatment. Otherwise, the desired movements of the anterior teeth cannot be obtained during retraction.

The bioprogressive treatment in orthodontics is a comprehensive treatment philosophy.

The primary objectives of bioprogressive therapy include to create a bite that functions well mechanically and contributes to the overall health of the masticatory system. Treatment plans consider the patient's facial aesthetics, aiming to improve or maintain facial harmony through orthodontic treatment. By addressing the underlying causes of malocclusion and considering growth patterns, the therapy aims to achieve stable, long-term results (Figure 3).

Figure 3. Illustrative demonstration of bioprogressive treatment in orthodontics.

In bioprogressive treatment, the teeth that require movement are moved within the vascular trabecular bone; the teeth that require anchorage are anchored to the cortical bone. In the construction of the utility arch, 0.016"x 0.016" and 0.016""x 0.022" It is recommended to use blue-elgiloy wire. A total of 60-80 g for the intrusion of the lower four incisors and 160-200 g for the intrusion of the upper four incisors are recommended [22,23].

Activation can be done in two ways, a tip back bend or a gable bend (V bend) at the step closer to the molar tube.This is the first activation method: The utility arch is initially placed passively. Activation is done through a V-bend facing occlusally in the posterior region of the vestibular segment.

In the other activation method, a type back bend is applied to the molar segment. When the arch is placed in the molar tube, the anterior segment extends towards the sulcus. When the utility archwire bypasses the canines and premolars and is connected to the four incisor brackets, these teeth are intruded. Type back bends are bent mesial to the 1st permanent molar tube on both sides at a 45° angle to the horizontal plane. The disadvantage of this method is distal bending of the molars. The use of transpalatal arch (TPA) has been proposed to prevent this effect in the upper arch [24].

The moment created by a force is related to the change in the distance between the point of application of the force and the center of resistance. In the incisor, if the force is applied labial to the center of resistance, the tooth proclines. As it approaches the center of resistance, the rate of intrusion increases. When the intrusion arch starts to work, torque variation occurs in the lower incisors. Shrof et al. stated that a relative intrusion is achieved in this system and that the deep bite is mostly corrected by the proclination of the incisors. He recommended the use of high-pull headgear for vertical control. They recommended this method for cases where the anterior teeth need protrusion [25].

In the study by Özsoy et al., they compared the incisor intrusion with utility arches and miniscrews: as a result, in the utility arch group, the upper molars showed a distal tilting movement. In the group using miniscrews, the intrusion force was applied closer to the centers of resistance of the upper molars, resulting in less proclination of the molars [26].

7. **Nanda's Connecticut Intrusion Arch (CTA)**

CTA is used to correct Class II malocclusion and deep bite. The CTA has the characteristics of both the utility arc and the traditional intrusion arc. It is made of nickel titanium alloy to provide shape memory, flexibility, light weight and continuous force distribution. It incorporates the features of the utility arc as well as those of the conventional intrusion arc. The CTA is manufactured with the proper bending required for easy placement and handling. It is available in two different lengths to accommodate mixed dentition cases [27].

The basic mechanism of the CTA for force transmission is a V-bend (V-twist) calibrated to transmit approximately 40-60 g of force. When in place, the V-bend is located just anterior to the molar brackets. When the arch is activated, a simple force system is created, consisting of a vertical force in the anterior region and a moment in the posterior region. Available in two different thicknesses to accommodate extraction, non-extraction and mixed dentition cases: 0.016” X 0.022” and 0.017” X 0.025”. The maxillary and mandibular versions have anterior dimensions of 34 mm and 28 mm respectively. Although in most cases the wire does not connect directly to the bracket slots, the anterior wire size is sufficient to allow this. A 0.018” X 0.025” auxiliary tube allows the CTA to be used with other wires. Piggyback wires and posterior segments can be used as needed. Transpalatal bars can be added to maintain buccal width or for anchorage [28–30].

Incisor intrusion requires approximately 50 g of force directed apically along the center of resistance of the tooth. Although the CTA is calibrated for this purpose, small differences in placement can alter the force system during activation. The moment created in the molar will also vary according to the amount of force in the incisors multiplied by the distance to the molars [30–32].

These small changes can be measured with a dynamometer when the arch is placed and adjustments can be made to ensure proper force distribution. It is recommended to insert triple tubes in maxillary molars and double tubes in mandibular molars. Approximately 1 mm of intrusion can be expected every six weeks [28,31,33].

8. **Extraoral Techniques: J Hooked Headgear**

J-hook headgear used as extraoral anchorage has been used in orthodontics for many years. Intrusion of the upper incisors is achieved by applying force to a tooth or a group of teeth through its hooks. The other name of this device is “Anterior High Pull Headgear” [34].

This appliance provides effective torque control as well as incisor intrusion. The advantages of the J-hook headgear are excellent anchorage control and variability in force (with adjustment of the force vector). Another advantage is the easy and safe use of this appliance by patients, as well as the simultaneous retraction of the teeth in both arches. The disadvantage of this technique is that the dental arch tends to widen and some pressure-related problems in the soft tissues of the skull rarely occur. In addition, this appliance requires good cooperation with the patient. The outcome of the treatment may be affected due to decreased cooperation during the treatment. In addition, the intermittent nature of the force is disadvantageous compared to other continuous and light force transmitting devices [35–37].

The use of an extraoral appliance in adults is socially difficult and is not preferred due to pain and dysfunction.

9. **Mechanics of Intrusion Using Orthodontic Mini-Screws and Selection of Mini Screws**

The introduction of Temporary Anchorage Devices (TADs) has revolutionized orthodontic treatment, offering a more reliable and controlled approach to tooth movement. TADs are small titanium screws placed in the jawbone to serve as a fixed anchor point from which forces can be applied to the teeth without relying on other teeth as anchors. This has significantly improved the efficiency of incisor intrusion by providing a direct and uninterrupted force. The use of TADs minimizes unwanted movement of adjacent teeth and allows for a more focused treatment approach. Their versatility and minimal invasiveness have made TADs a preferred option for many orthodontists.

When another tooth or group of teeth is used as an anchor during tooth movement, the force affects both segments and is distributed in equal and opposite directions, so some unwanted movements occur in these support teeth as a side effect. Although successful results are obtained with continuous arches and segmental arches, these methods require support from the patient's other teeth to intrude the incisors. However, when mini implants that can be fixed to the upper and lower arch are used, the force applied affects only the teeth to be moved. This makes implants an ideal anchorage option [37].

Mini-screws can be divided into two groups according to the insertion method: self-tapping or self-drilling. Self-tapping screws are inserted after a guide groove is prepared, whereas with self-drilling screws, the practitioner inserts these screws directly into the area to be applied by turning them with a screwdriver. Even if there is a possibility of screw fracture with the latter method, the high bone-implant contact achieved after insertion has been reported to lead to better primary stability [38–40].

When placing mini screws, attention is paid to the distance between the roots. There may be differences in diameter and size. In order to protect the periodontium, miniscrews should have a distance of 1 mm between the root, and a diameter of 1.5 mm or less is preferred. The miniscrews placed in the anterior region of the maxilla can be placed between the roots of the maxillary central teeth under the anterior nasal spinna, or between the roots of the central-lateral or lateral-canine teeth. The size of the miniscrews used also varies [41,42].

Kanomi used orthodontic mini implants for mandibular incisor intrusion for the first time. Kanomi published a case report with deep bite in which he obtained 6 mm intrusion at the end of 4 months with implants placed between the root tips of the mandibular incisors and reported that the implants did not cause resorption of the roots and no pathology in the peridontal tissues [43].

Ohnishi et al. treated a 19-year-old patient with severe deep overbite and a gummy smile with using mini-implants. The mini-implant was placed between two incisors 3 mm above the apex and a light force of 20 g was applied with a ligature wire over a continuous archwire. No tooth extraction was performed in the upper and lower jaws. The deep bite was reduced from 7.2 mm to 1.7 mm (upper incisors were intruded 5.5 mm) and the gummy smile was corrected. During the 2-year follow-up period, no relapse was observed. No change in molar position was observed to cause posterior rotation of the mandible [44].

Polat Özsoy et al. intruded the upper incisor 1.92 mm at 4.55 months [26].

10. **Incisor Intrusion with Clear Aligners**

The intrusion of incisors with aligners is an orthodontic treatment procedure aimed at correcting the vertical position of the incisors by moving them upwards into the bone. This treatment is often necessary for patients with deep overbites, excessive gingival display, or to correct the overall bite. Aligners, popularly known by brand names like Invisalign, are clear, removable orthodontic devices that apply controlled force to teeth to move them into the desired position over time. Intrusion of incisors with aligners is a significant aspect of orthodontic treatment. Several studies have investigated the effectiveness of different methods for incisor intrusion. For instance, demonstrated statistically significant incisor intrusion with mini implants [45]. reported a mean resorption of 0.6 mm within a 4.3-month period using intrusion arches for maxillary incisor intrusion [46]. Additionally, highlighted the limited information on root resorption of incisors with anteriorly placed mini-implant-assisted intrusion mechanics [47]. Furthermore, emphasized the importance of considering the position of maxillary incisors in determining the type of treatment for overbite correction [48].

Figure 4. Illustrative demonstration of treatment with clear aligners.

Assessment and Planning: An orthodontist assesses the patient's dental structure through exams and imaging techniques like X-rays or 3D scans. The information is used to create a detailed treatment plan, including the extent of intrusion needed.

Custom Aligners: Based on the treatment plan, a series of custom-made aligners are produced. Each aligner is slightly different, moving the teeth incrementally towards the desired position. The patient must wear the aligners for the recommended time each day, usually 20-22 hours.

Controlled Force Application: Aligners exert controlled force on the incisors to intrude them into the bone. The movement is gradual and requires changing aligners every 1-2 weeks to continue applying the correct amount of force.

Monitoring Progress: Regular check-ups with the orthodontist are necessary to monitor the progress and make adjustments to the treatment plan if needed.

Effectiveness: Intrusion of incisors with aligners is effective for many patients, but the success rate can depend on the complexity of the case, patient compliance with wearing the aligners, and individual biological response to treatment.

Duration: The total treatment time varies depending on the extent of intrusion required and the patient's adherence to the treatment plan. It can range from a few months to a couple of years.

Attachments and Auxiliary Techniques: Sometimes, to achieve the desired intrusion, the orthodontist may use attachments or buttons that are temporarily bonded to the teeth. These attachments help in applying the necessary force more effectively.

Limitations: While aligners are versatile, there may be limitations to their ability to intrude incisors, especially in severe cases. Some situations may require adjunctive treatments or alternative orthodontic methods.

Comfort and Aesthetics: Aligners are generally considered more comfortable and aesthetically pleasing compared to traditional braces. However, patients may experience some discomfort or pressure when a new set of aligners is first worn.

Intrusion of incisors with aligners is a sophisticated orthodontic treatment that requires careful planning and patient cooperation. It offers a less visible alternative to traditional braces and can effectively address certain dental issues. However, it's important for patients to have realistic expectations and follow their orthodontist's instructions closely for the best outcomes.

B. **Amount of Force Applied in the Intrusion of the Incisors**

When applying intrusion, the lowest possible force is preferred to minimize the harmful effects on the root of the tooth and the surrounding periodontium. When the force increases, the risk of root resorption increases and an undesirable extrusion occurs due to the reciprocal effect on the posterior teeth. Burstone recommended a force of 25 g per tooth for the upper central teeth and a total of 40 g for the lower 4 incisors. Nanda reported that an intrusion force of 15 g for the upper central incisors, 10 g for the upper lateral incisors, 25 g for the upper canines, 50-60 g for the total of the upper 4 incisors and 40 g for the lower 4 incisors did not cause extrusion. Weiland et al. argued in their study that the application of 40-50 gr. intrusive force for four mandibular incisors would not cause any negative effect on the posterior segment. Bench et al. stated that a total force of 60-80 g, 20 g per tooth, is ideal for the intrusion of four mandibular incisors. McNamara stated that 25 g per tooth is ideal for lower incisor intrusion [1,7,23,49].

Intrusion of the canines together with the incisors requires higher forces, which results in extrusion as a side effect in the posterior region. In addition, the application of higher forces carries a higher risk of root resorption of the incisors, so the inclusion of the canines is not recommended.

The amount of incisor intrusion and the forces involved in the process are critical considerations in orthodontic treatment. Various studies have investigated the effectiveness of different methods and the impact of forces on incisor intrusion.

Sosly et al. conducted a systematic review and meta-analysis, which indicated that miniscrews placed bilaterally between the maxillary central and lateral incisors resulted in genuine incisor intrusion. This finding suggests that the placement of miniscrews can influence the amount of incisor intrusion [50].

Jiang et al. utilized a 3D finite element study to design retraction and intrusion combinations for incisors, reporting a total movement amount of 0.25 mm. This study provides insights into the specific amount of movement achieved through different combinations of forces for incisor intrusion [51].

Atik et al. evaluated changes in the maxillary alveolar bone after incisor intrusion and highlighted the biomechanical explanation for different amounts of incisor intrusion related to the use of continuous force versus a linear decrease of force. This study emphasizes the influence of force application on the amount of incisor intrusion and its impact on the alveolar bone [52].

Furthermore, Aras & Tuncer and Namrawy et al. compared different methods of incisor intrusion and reported varying intrusion rates with different intrusive forces [34,38]. These findings underscore the importance of considering the magnitude of intrusive forces in achieving the desired amount of incisor intrusion.

Research demonstrated that the amount of incisor intrusion did not change significantly when forces varied from 40 to 80 g, indicating that incisor intrusion does not necessarily require large amounts of force [44,50].

In conclusion, the amount of incisor intrusion and the forces involved are influenced by various factors, including the method of intrusion, the placement of miniscrews, and the magnitude of intrusive forces. Understanding these factors is essential for achieving effective and controlled incisor intrusion in orthodontic treatment.

C. **Conclusions**

The intrusion of incisors is a complex orthodontic procedure that requires careful planning and execution. Traditional fixed appliances, TADs, and clear aligner technology represent the primary mechanics used in this process, each with its advantages and limitations. The choice of technique depends on various factors, including the severity of the case, patient preferences, and clinical considerations. With the ongoing advancements in orthodontic research and technology, the mechanics of incisor intrusion continue to evolve, offering more efficient and patient-friendly treatment options. Ultimately, the success of incisor intrusion relies on a comprehensive understanding of orthodontic mechanics and a personalized approach to treatment planning.

REFERENCES

[1] Burstone, C.J. (2001). Biomechanics of deep overbite correction. *Seminars in Orthodontics*. DOI: 10.1053/sodo.2001.21059.

[2] Preston, C.B. et al. (2008). Long-term effectiveness of the continuous and the sectional archwire techniques in leveling the curve of Spee. *American journal of orthodontics and dentofacial orthopedics : official publication of the American Association of Orthodontists, its constituent societies, and the American Board of Orthodontics*. DOI: 10.1016/j.ajodo.2006.02.039.

[3] Mavragani, M. (2000). A radiographic comparison of apical root resorption after orthodontic treatment with a standard edgewise and a straight-wire edgewise technique. *The European Journal of Orthodontics*. DOI: 10.1093/ejo/22.6.665.

[4] Maués, C.P.R. et al. (2015). Severe root resorption resulting from orthodontic treatment: Prevalence and risk factors. *Dental Press Journal of Orthodontics*. DOI: 10.1590/2176-9451.20.1.052-058.oar.

[5] Antony Margaret, V. et al. (2013). A Clinical Evaluation of Three Force Delivery Systems in Stage II of the Begg Technique. *The Journal of Indian Orthodontic Society*. DOI: 10.5005/jp-journals-10021-1206.

[6] Laxmikanth, S.M. et al. (2019). Begg's Revisited: Report of a Case. *Journal of Indian Orthodontic Society*. DOI: 10.4103/jios.jios_71_18.

[7] Burstone, C.R. (1977). Deep overbite correction by intrusion. *American journal of orthodontics*. DOI: 10.1016/0002-9416(77)90121-x.

[8] de Almeida, M.R. et al. (2018). A comparative study of the effect of the intrusion arch and straight wire mechanics on incisor root resorption: A randomized, controlled trial. *The Angle Orthodontist*. DOI: 10.2319/06417-424R.

[9] Bardideh, E. et al. (2023). The Effects of Intrusion of Anterior Teeth by Skeletal Anchorage in Deep Bite Patients; A Systematic Review and Meta-Analysis. *Biomimetics*. DOI: 10.3390/biomimetics8010101.

[10] Roberts, W.E. et al. (2015). Biology of biomechanics: Finite element analysis of a statically determinate system to rotate the occlusal plane for correction of a skeletal Class III open-bite malocclusion. *American Journal of Orthodontics and Dentofacial Orthopedics*. DOI: 10.1016/j.ajodo.2015.10.002.

[11] de Brito, G.M. et al. (2019). Pure Mandibular Incisor Intrusion: A Finite Element Study to Evaluate the Segmented Arch Technique. *Materials*. DOI: 10.3390/ma12172784.

[12] Goel, P. et al. (2014). A comparative study of different intrusion methods and their effect on maxillary incisors. *Journal of Oral Biology and Craniofacial Research*. DOI: 10.1016/j.jobcr.2014.11.007.

[13] Shintcovsk, R.L. et al. (2018). Evaluation of the load system produced by a single intrusion bend in a maxillary lateral incisor bracket with different alloys.

The Angle Orthodontist. DOI: 10.2319/081717-556.1.

[14] Lira, A. de L.S. de and Alexandrino, Y.N. de S. (2015). Comparison of two types of biomecanics for deep overbite correction. *Brazilian Journal of Oral Sciences*. DOI: 10.1590/1677-3225v14n1a14.

[15] Kaur Randhawa, G. et al. (2019). The effects on pdl, tooth and alveolar bone with intrusion of anteriors using round wire utility arch: finite element model analysis. *IP Indian Journal of Orthodontics and Dentofacial Research*. DOI: 10.18231/j.ijodr.2019.019.

[16] Sifakakis, I. et al. (2009). Forces and Moments Generated with Various Incisor Intrusion Systems on Maxillary and Mandibular Anterior Teeth. *The Angle Orthodontist*. DOI: 10.2319/120908-622.1.

[17] Cruz, J.D. et al. (2023). EFFECTS OF 2x4 APPLIANCE AND NiTi OPEN SPRING ON MIXED DENTITION. *Revista Contemporânea*. DOI: 10.56083/RCV3N7-040.

[18] PATRA, A. et al. (2023). Management of an impacted maxillary central incisor with surgical exposure and a 2x4 orthodontic appliance: A case Report. *Journal of Medical Research and Reviews*. DOI: 10.5455/JMRR.20230711045100.

[19] Tsiopas, N. et al. (2013). A 40 years follow-up of dental arch dimensions and incisor irregularity in adults. *The European Journal of Orthodontics*. DOI: 10.1093/ejo/cjr121.

[20] Jain, R.K. (2014). Comparison of Intrusion Effects on Maxillary Incisors Among Mini Implant Anchorage, J-Hook Headgear and Utility Arch. *JOURNAL OF CLINICAL AND DIAGNOSTIC RESEARCH*. DOI: 10.7860/JCDR/2014/8339.4554.

[21] N, P.M. (2021). Treatment Of Class Ii Division 2 Pattern Malocclusion Using Protraction Utility Arch: A Clinical Case Report (Case Report). *Global Journal of Dental Specialty*. DOI: 10.53647/GJDS.2021.v01i02.05.

[22] Mahfouz, M. (2014). Face Adaptation in Orthodontics. *Open Journal of Stomatology*. DOI: 10.4236/ojst.2014.47045.

[23] McNamara, J.A. (1986). Utility arches. *Journal of clinical orthodontics : JCO*.

[24] Shroff, B. et al. (1997). Simultaneous intrusion and retraction using a three-piece base arch. *The Angle orthodontist*. DOI: 10.1043/0003-3219(1997)067<0455:SIARUA>2.3.CO;2.

[25] van Steenbergen, E. et al. (2005). The influence of force magnitude on intrusion of the maxillary segment. *The Angle orthodontist*. DOI: 10.1043/0003-3219(2005)75[723:TIOFMO]2.0.CO;2.

[26] Polat-Özsoy, Ö. et al. (2011). Comparison of the intrusive effects of miniscrews and utility arches. *American journal of orthodontics and dentofacial orthopedics : official publication of the American Association of Orthodontists, its constituent societies, and the American Board of Orthodontics*. DOI: 10.1016/j.ajodo.2009.05.040.

[27] Mathew, T. and Shoji, Y. (2014). Camouflage of Class II Division I malocclusion with retrusion utility arch: A case report. *International Journal of Medical and Dental Case Reports*. DOI: 10.15713/ins.ijmdcr.15.

[28] Janakiraman, N. et al. (2016). Response of the maxillary dentition to a statically determinate one-couple system with tip-back mechanics: A prospective clinical trial. *The Angle Orthodontist*. DOI: 10.2319/012815-68.1.

[29] Trpevska, V. et al. (2021). DEEP BITE CORRECTION BY INCISORS INTRUSION WITH CONNECTICUT INTRUSION ARCH - case report. *Journal of Morphological Sciences*. DOI: 10.55302/JMS2142135t.

[30] Makhija, P. et al. (2012). MAK Bends and MAK Stops: An Innovative Way to put Bends and Stops in NiTi Archwires. *The Journal of Indian Orthodontic Society*. DOI: 10.5005/jp-journals-10021-1094.

[31] El Beali, A. et al. (2011). Evaluation of the connecticut intrusion arch in leveling deep curve of Spee. *Egyptian Orthodontic Journal*. DOI: 10.21608/eos.2011.78918.

[32] Upadhyay, M. and Nanda, R. (2015). Management of Deep Overbite Malocclusion, in *Esthetics and Biomechanics in Orthodontics*, Elsevier, pp. 133–146.

[33] Bardideh, E. et al. (2023). The Effects of Intrusion of Anterior Teeth by Skeletal Anchorage in Deep Bite Patients; A Systematic Review and Meta-Analysis. *Biomimetics*. DOI: 10.3390/biomimetics8010101.

[34] El Namrawy, M.M. et al. (2019). Intrusive Arch versus Miniscrew-Supported Intrusion for Deep Bite Correction. *Open Access Macedonian Journal of Medical Sciences*. DOI: 10.3889/oamjms.2019.332.

[35] Aydoğdu, E. and Özsoy, Ö.P. (2011). Effects of mandibular incisor intrusion obtained using a conventional utility arch vs bone anchorage. *The Angle Orthodontist*. DOI: 10.2319/120610-703.1.

[36] Salem, M. and Hewy, E. (2021). Comparison of Two Different Mini-Implant Position in Maxillary Incisors Intrusion (Cone Beam Study). *Al-Azhar Assiut Dental Journal*. DOI: 10.21608/aadj.2021.208208.

[37] Hewy, E. et al. (2021). A comparative Study of Different Methods of Maxillary Incisors Intrusion(Cone Beam Study). *Al-Azhar Assiut Dental Journal*. DOI: 10.21608/aadj.2021.164175.

[38] Aras, I. and Tuncer, A. V. (2016). Comparison of anterior and posterior mini-implant-assisted maxillary incisor intrusion: Root resorption and treatment efficiency. *The Angle Orthodontist*. DOI: 10.2319/085015-571.1.

[39] Carrillo, R. et al. (2007). Intrusion of multiradicular teeth and related root resorption with mini-screw implant anchorage: A radiographic evaluation. *American Journal of Orthodontics and Dentofacial Orthopedics*. DOI: 10.1016/j.ajodo.2006.08.017.

[40] Elias, C.N. et al. (2012). Orthodontic Implants: Concepts for the Orthodontic Practitioner. *International Journal of Dentistry*. DOI: 10.1155/2012/549761.

[41] Singh, J. et al. (2021). Comparative Evaluation of Primary Stability of Two Different Types of Orthodontic Mini-Implants. *Journal of Pharmacy and Bioallied Sciences*. DOI: 10.4103/jpbs.JPBS_604_20.

[42] Mizrahi, E. (2016). The use of Miniscrews in Orthodontics: A Review of Selected Clinical Applications. *Primary Dental Journal*. DOI: 10.1308/205016816820209569.

[43] Kanomi, R. (1997). Mini-implant for orthodontic anchorage. *Journal of clinical orthodontics : JCO*.

[44] Ohnishi, H. et al. (2005). A mini-implant for orthodontic anchorage in a deep overbite case. *The Angle orthodontist*. DOI: 10.1043/0003-3219(2005)75[444:AMFOAI]2.0.CO;2.

[45] Jain, R.K. (2014). Comparison of Intrusion Effects on Maxillary Incisors Among Mini Implant Anchorage, J-Hook Headgear and Utility Arch. *JOURNAL OF CLINICAL AND DIAGNOSTIC RESEARCH*. DOI: 10.7860/JCDR/2014/8339.4554.

[46] de Almeida, M.R. et al. (2018). A comparative study of the effect of the intrusion arch and straight wire mechanics on incisor root resorption: A randomized, controlled trial. *The Angle Orthodontist*. DOI: 10.2319/06417-424R.

[47] Hewy, E. et al. (2021). A comparative Study of Different Methods of Maxillary Incisors Intrusion(Cone Beam Study). *Al-Azhar Assiut Dental Journal*. DOI: 10.21608/aadj.2021.164175.

[48] El Namrawy, M.M. et al. (2019). Intrusive Arch versus Miniscrew-Supported Intrusion for Deep Bite Correction. *Open Access Macedonian Journal of Medical Sciences*. DOI: 10.3889/oamjms.2019.332.

[49] Weiland, F.J. et al. (1996). Evaluation of continuous arch and segmented arch leveling techniques in adult patients--a clinical study. *American journal of orthodontics and dentofacial orthopedics : official publication of the American Association of Orthodontists, its constituent societies, and the American Board of Orthodontics*. DOI: 10.1016/s0889-5406(96)80042-4.

[50] Sosly, R. et al. (2020). Effectiveness of miniscrew-supported maxillary incisor intrusion in deep-bite correction: A systematic review and meta-analysis. *The Angle orthodontist*. DOI: 10.2319/061119-400.1.

[51] Jiang, T. et al. (2020). Clear aligners for maxillary anterior en masse retraction: a 3D finite element study. *Scientific reports*. DOI: 10.1038/s41598-020-67273-2.

[52] Atik, E. et al. (2018). Evaluation of changes in the maxillary alveolar bone after incisor intrusion. *Korean journal of orthodontics*. DOI: 10.4041/kjod.2018.48.6.367.

List of Figures and Tables

CHAPTER 2

RATIONAL ANTIBIOTIC USE IN DENTISTRY IN THE AGE OF ANTIBIOTIC RESISTANCE

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The concept of "Rational Antibiotic Use"

Etymologically, the word "antibiotic" means "against living things." However, in actuality, antibiotics predominantly refer to drugs directed against bacteria and other microorganisms. Although antibiotics are drugs with immune-boosting, infection-preventing, and therapeutic properties, the development of antimicrobial resistance has not been prevented due to factors such as prescription errors, unstandardized empirical treatments, failure to distinguish between colonization and infection, inadequate dosages, and incorrect or unnecessarily prolonged use.

Antimicrobial resistance (AMR) is a global threat that causes the deaths of 700,000 people annually. If urgent action plans are not implemented, it is estimated that it will lead to 10 million deaths by 2050 and result in significant economic losses[1]. The World Health Organization (WHO) defines drug resistance in its Global Action Plan on AMR as a threat to the sustainability of the global public health response to the persistent threat of infectious diseases. In European countries, daily prescribed antibiotic doses are shown in Figure 1 in the WHO's Antibiotic Consumption Surveillance report, with Turkey being observed as the top consumer of antibiotics. The report indicates that the "irrational" use of antimicrobial drugs accelerates the development of AMR, leading to the development of approaches aimed at optimizin g the use of antimicrobials in both medical and veterinary fields. In particular, the development of AMR in low- and middle-income countries has led to the implementation of measures for the management and restrictive use of antimicrobials within the framework of the Global Action Plan.

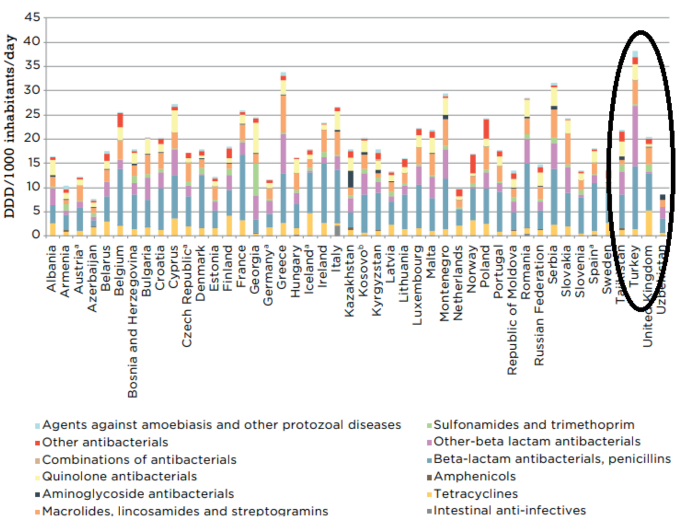

Figure 1. Antibiotic doses consumed by 1000 people per day per person in Europe. (WHO Report on Surveillance of Antibiotic Consumption, 2015)

Rational Drug Use is ensuring that a medication is correct in five ways before it is used to prevent, control, or treat a disease.

- The right medicine,
- for the right person
- the right amount,
- right time,
- correctly (such as oral, im, iv)

The principles of rational drug use consist of four main elements: effectiveness, safety, appropriateness, and cost. For the ideal use of antibiotics, the right antibiotic should be administered after a correct diagnosis, in the most suitable way, at an effective dosage, with optimal intervals, and for an appropriate duration. For proper antibiotic usage, the presence of a microbiologically confirmed bacterial infection must always be investigated. Antibiotics are considered to be used inappropriately when they are used without a clinical microbiological diagnosis, in the absence of infection, when the chosen antibiotic is incorrect, when the antibiotic dosage is inadequate or excessive, and when the dosing intervals are inappropriate. Additionally, selecting a more expensive antibiotic instead of one with known effectiveness, using multiple antibiotics simultaneously when not necessary, and using an antibiotic to which the causative microorganism identified in culture is naturally resistant also constitute inappropriate use.

Possible situations related to incorrect antibiotic use:

1.When antibiotics are prescribed unnecessarily.

2.When broad-spectrum antibiotics are widely used or narrow-spectrum antibiotics are used incorrectly.

3. When the antibiotic dose is higher or lower than the appropriate dose for that patient.

4.When the duration of antibiotic treatment is excessively long or too short.

5. When antibiotic treatment is not changed when necessary according to microbiological culture and antibiogram results.

6.When more than two antibiotics are used simultaneously without proper indication.

7.When unnecessary and/or prolonged surgical prophylaxis is administered.

When a patient (human or animal) receives antibiotics without a genuine need, it not only provides no benefit but also poses risks in terms of side effects (e.g., allergic reactions, toxicity, C. difficile infections, etc.). It has been reported that adverse effects due to irrational antibiotic use were observed in one out of five hospitalized patients[2].

What is the situation regarding antimicrobial resistance in oral pathogens?

Dental infections are typically caused by obligatory anaerobic, gram-positive aerobic, and facultative bacteria, leading to polymicrobial infections. In the treatment of infections caused by these bacteria, penicillin V, amoxicillin, amoxicillin-clavulanic acid, ampicillin, metronidazole, and first-generation cephalosporins, as well as macrolide antibiotics, are commonly used.

As for oral pathogens, infective endocarditis is often associated with oral Streptococ, while Peptostreptococ are responsible for gum and root infections. Bacteroides species are associated with dental plaque and abscesses, Fusobacterium nucleatum and Porphyromonas species are frequently isolated from infected root canals, and Prevotella species are the most commonly isolated oral pathogens in mandibular abscesses[3].

The biofilm layer in which many bacteria constituting the oral microbiota reside has been found to exhibit much higher antibiotic resistance compared to planktonic bacteria. This is due to the socio-microbiology resulting from the structure, physiology, and quorum sensing (QS) mechanism of the biofilm environment[3]. Various ecological pressures in the oral cavity are a result of physical and chemical changes in this environment, necessitating adjustments in the metabolic and genomic activities of oral microbiota members to cope with such stress. Therefore, the nature of oral biofilm can support various complex bacterial interactions, including horizontal gene transfer (HGT)[4].

In Bacteroides, Capnocytophaga and Prevotella, the mobA β-lactamase gene confers resistance to these three genera horizontally. The conjugation of bidirectional erythromycin resistance genes between Streptococcus gordonii and Enterococcus faecalis is facilitated through the pAM81 plasmid pathway, resulting in the transfer of erythromycin resistance to transconjugants at rates ranging from 10^{-3} to 10^{-6} within 24 to 72 hours[5].

Staphylococcus aureus plays a significant role in the development of periodontal disease and exhibits high-level beta-lactam resistance. According to the most recent antibiotic guidelines[6], the initiation of amoxicillin and metronidazole is recommended for individuals under 40 years old who develop periodontal disease rapidly[6]. However, systemic antimicrobials are not recommended for individuals over 40 years old with slow-progressing periodontitis. The presence of beta-lactam resistance genes such as BlaZ in periodontal diseases caused by Staphylococcus makes antimicrobial treatment unsuccessful[6].

In a study conducted on the oral flora commensals known as Streptococcus salivarius, Veillonella, and Viridans Streptococ, antimicrobial resistance genes were found to be highly prevalent even in these flora bacteria. In the study, the mef(A/E) resistance gene was detected in 65% of the S. salivarius isolates[7].

Antibiotic resistance that develops against glycopeptide antibiotics in Enterococci poses serious challenges in treatment, given the wide range of infections caused by Enterococci. So far, various gene clusters responsible for vancomycin resistance have been identified in Enterococci, ranging from van A to van G. Among these glycopeptide resistance types, the best-defined ones are Van A, Van B, Van C, and Van D resistances[8].

One of the most common antimicrobial resistance genes in oral pathogens is the tet(M) gene. Many studies have shown that the tet(M) gene is located within the Tn916 transposon and is responsible for transferring tet(M) gene from Neisseria species in root canals to Enterococcus faecalis. Because root canals are isolated from the normal flora of the oral cavity and provide an environment where bacteria can evade the immune system, tetracycline resistance is commonly observed in these bacteria in root canals[8].

Research has shown that the tet(M) gene is more widespread in the oral flora of babies born vaginally, while tet(Q) is more common in babies born via cesarean section[7,8].

In general, countries with higher antibiotic consumption tend to have a higher number of antibiotic resistance genes.

Commonly Used Antibiotics and Prophylaxis in Dentistry

1) Penicillins

1.1) Penicillin V

Penicillin V is a narrow-spectrum, low-toxicity, highly effective antibiotic. It is effective against microorganisms such as Streptococ, facultative, and obligate anaerobic bacteria. It is among the first-choice antibiotics for the treatment of dental infections. It is metabolized in the liver and excreted rapidly through the kidneys. In individuals with renal insufficiency, dose adjustments are made in consultation with the relevant healthcare provider. The use of Penicillin V is contraindicated in individuals who exhibit hypersensitivity reactions[9,10].

1.2. Ampicillin

Ampicillin is an effective antibiotic against bacteria sensitive to Penicillin G, including gram-positive bacteria, shigella, neisseria, salmonella, and enterococci. Ampicillin reduces the effectiveness of oral contraceptives. It interacts with tetracycline, chloramphenicol, lincomycin, veromycin, oral contraceptives, heparin, and anticoagulant drugs[9,11].

1.3. Amoxicillin

Amoxicillin is a highly safe semi-synthetic penicillin with a broad spectrum of activity against gram-negative bacteria. Its gastrointestinal absorption is rapid and efficient. In cases where renal insufficiency is identified in the patient's medical history, consultation with the relevant physician is necessary to adjust the medication dosage. When taken in equivalent doses with ampicillin, amoxicillin results in twice the blood concentration of ampicillin[12,13].

1.4. Broad-Spectrum Penicillins with Beta-Lactamase Inhibitors

Penicillins, due to their inability to effectively combat many bacteria that produce beta-lactamases, have been combined with different penicillins like clavulanic acid and sulbactam (beta-lactamase inhibitors) to create a broad-spectrum effect (e.g., amoxicillin + clavulanic acid or ampicillin + sulbactam). Amoxicillin with clavulanic acid, taken orally, has high efficacy in dental infections. Known side effects include tongue discoloration, black hairy tongue, and candidiasis[14]. For individuals with renal insufficiency, consultation with the relevant physician may be necessary to adjust the dosage[12,15].

2. Cephalosporins

Cephalosporins have antibacterial effects similar to penicillins and are limited in use for dental infections. Within the cephalosporin groups, the effectiveness against gram-negative and gram-positive bacteria varies with each generation. They can cause gastrointestinal side effects, interact with aspirin and anticoagulants, and have nephrotoxic potential. Individuals with a history of penicillin allergy should not use cephalosporin derivative drugs[14,16].

3. Macrolides

Macrolides work by inhibiting protein synthesis. Drugs in this group include Erythromycin, Clarithromycin, and Azithromycin. Azithromycin is highly effective against anaerobic bacteria. Erythromycin is preferred for individuals with penicillin allergies and for the treatment of mild to moderate dental infections. Clarithromycin is the most effective antibiotic for individuals allergic to penicillin. Dosage adjustments are necessary for patients with renal insufficiency, and its use should be avoided in severe liver disease. Patients with a medical history of such conditions should be referred to their physicians for consultation. Side effects such as arrhythmia, headaches, gastrointestinal problems, and skin rashes should be communicated to the patient[14].

4. Lincosamides

Lincosamides work by disrupting protein synthesis. Clindamycin and lincomycin belong to this group. Clindamycin has a higher antibacterial efficacy compared to lincomycin. Their antibacterial spectrum and mechanisms of action are similar to macrolides. Clindamycin is preferred when dental infections with bone involvement and abscesses spread to the bone require treatment beyond what penicillin and erythromycin can provide, due to its ability to penetrate bone tissue and abscesses. Dosage adjustments should be made for patients with liver insufficiency. The most common side effect is severe colitis[14,17].

4.1. Clindamycin

Clindamycin is commonly used in cases of dental infections accompanied by osteomyelitis due to its good distribution in body fluids, especially bone tissue. It is preferred for individuals with penicillin allergies. Dosage adjustments are necessary for individuals with liver disease. If diarrhea occurs, treatment should be discontinued promptly as it can lead to pseudomembranous colitis[12,18].

5. Tetracyclines

Tetracyclines inhibit protein synthesis and exhibit bacteriostatic effects. Doxycycline, found within this group, is preferred due to its long duration of action. Tetracyclines not only have direct antimicrobial and anti-inflammatory properties but also inhibit osteoclast activity, bone resorption, and collagenase activity[19,20]. They can be used in the treatment of dental infections that are not sensitive to penicillin and erythromycin. Consultation with relevant physicians is required for dosage adjustments in individuals with renal insufficiency. Its use is contraindicated in children under 8 years of age due to tooth discoloration and in pregnant women due to teratogenic effects. Care should be taken regarding food and drug interactions when using tetracycline with dairy and dairy products, aluminum, calcium, and magnesium-containing antacids, and iron, as the absorption of tetracycline in the intestines may be reduced[16,21].

6. Metronidazole

Metronidazole is an effective bactericidal drug against anaerobic microorganisms. It can be used in conjunction with penicillins for periodontal infections[14]. Individuals with renal insufficiency and liver disease should be referred to a consulting physician for dosage adjustments. Common side effects include a metallic taste in the mouth, a furry tongue, and gastrointestinal side effects. Caution should be exercised when using metronidazole alongside alcohol[12,15,18].

Antimicrobial Prophylaxis in Dentistry

In dentistry, antibiotics are used not only for treatment but also for prophylactic (preventive) purposes. One-third of the antibiotics prescribed by dentists are for prophylactic applications, indicating that prophylactic use is quite common[22]. Studies have identified over 700 different bacteria in the oral cavity, with viridans group streptococ being the most common among them[23]. The aim of antibiotic prophylaxis (AP) is to prevent the spread of these microorganisms within the oral cavity to other parts of the body during procedures that could lead to bleeding[22,24].

Bacteremia resulting from dental treatments can occur at rates of 10-100% during tooth extractions, 36-88% during periodontal surgeries, 8-80% during scaling and root planing treatments, 40% during dental cleaning, 9-32% during rubber dam placement, and 20% during endodontic treatments[25,26]. Bacterial passage is also observed during daily routine activities, including tooth brushing (20-68%), flossing (20-68%), wooden toothpick use (20-40%), oral irrigator use (7-50%), and chewing food (7-51%)[27].

Antibiotic prophylaxis (AP) should be chosen only for dental procedures where there is a risk of infection. It should be administered to achieve an appropriate bactericidal concentration during the incision and at the right time. Additionally, it should be given as soon as possible without causing hypersensitivity, toxicity, superinfection, resistance, and cost issues[22]. In healthy individuals with normal immune systems, AP may generally not be necessary because the number of bacteria entering the bloodstream is limited[28]. The necessity of prophylactic use, which situations are included, and the choice of the drug should be carefully evaluated (Table 1). Prophylactic antibiotic use may be required, especially in patients at risk of endocarditis or those with weakened immune systems.

Suggested Situations for Antibiotic Prophylaxis

1. Groups of Patients at Risk for Bacterial Endocarditis

- High-risk individuals

Those carrying prosthetic heart valves

Those with a history of previous bacterial endocarditis

Individuals with complex cyanotic congenital heart disease

Those with heart valve damage due to rheumatic fever

- Moderately at-risk individuals

Congenital cardiac malformations

Acquired valve dysfunction

Hypertrophic cardiomyopathy

Mitral valve prolapse

- Low-risk individuals

Those who have undergone coronary artery bypass surgery

Individuals with physiological, functional, and innocent heart murmurs

Those with unregulated mitral valve prolapse

Isolated secundum atrial septal defect

Those who have undergone surgical repair of atrial septal defect

2. Groups of Patients with Artificial and Transplanted Organs

3. Patients who have undergone splenectomy (spleen removal)

4. Patients treated with implants for hydrocephalus

5. Those who have received or are currently undergoing treatment for nephritis

6. Those who have had their immune ability reduced

- Due to illness:

Aplastic anemia

Agranulocytosis

Lupus erythematosus

Uncontrolled diabetes

- Due to medications:

Antineoplastic drugs

Immunosuppressive drugs

Adrenal corticosteroids

Radiotherapy

7. Patients with orofacial pain, traumatic injuries, and maxillomandibular fractures

8. Individuals with Down syndrome who have cardiovascular anomalies

Antibiotic Prophylaxis Required Dental Procedures:

Dental procedures involving manipulation of gingival tissue in the periapical region or perforation of oral mucosa.

Dental Procedures Not Requiring Antibiotic Prophylaxis:

Restorative dental procedures where retraction cords are not used.

Local anesthesia injections that are not intraligamentary.

Endodontic treatment, extraction, or replacement.

Placement of a rubber dam.

Suture removal.

Fluoride treatments.

Fitting of removable prosthetic and orthodontic appliances.

Oral radiography.

Extraction of deciduous (baby) teeth[29].

It is important for dentists who prescribe antibiotics for the treatment and prophylaxis of dental infections to have sufficient knowledge about these medications. They should not use antibiotics randomly and in inappropriate ways. It is important for them to prescribe antibiotics in accordance with rational drug use principles for each indication, with the correct format and content information. Additionally, they should successfully perform other treatment procedures and provide appropriate advice to the patient. They should contribute to the treatment process by adequately informing the patient and effectively managing the process, making the patient a collaborative partner in the treatment.

Just like in other professions, medical or dental education includes post-graduate education. The rapidly changing nature of knowledge has made such education a mandatory requirement. These trainings enable healthcare professionals to access and continue practicing with up-to-date information, allowing for the implementation of best practices.

Situation	Agent	Regimen: Single Dose 30 to 60 min Before Procedure	
		Adults	Children
Oral	Amoksisilin	2 gr	50 mg/kg
Unable to take oral medication	Ampisilin Sefazolin Ceftriakson	2 gr IM or IV 1 gr IM or IV	50 mg/kg IM or IV
Allergic to penicillins or ampicillin—oral	Cephalexin Klindamisin Azitromisin Klaritromisin	2 gr 600 mg 500 mg	50 mg/kg 20 mg/kg 15 mg/kg
Allergic to penicillins or ampicillin and unable to take oral medication	Sefazolin Ceftriakson Klindamisin	1 gr IM or IV 600 mg IM or IV	50 mg/kg IM or IV 20 mg/kg IM or IV

Table 1: Regimens for a Dental Procedure[30]. *(IM: intramuscular, IV: intravenous)*

A Single Health Approach in Rational Antibiotic Use

One Health is an approach and practice based on the principle that "prevention is better than cure" in order to provide better healthcare to the public. It is a multidisciplinary approach that relies on multisectoral communication and aims to develop common policies and ideas against potential threats to health in the future. It involves collaborative research among different disciplines to holistically protect health[31]. The One Health approach considers humans, animals, and the ecosystem as a whole on the same planet and works together to address common problems. Antimicrobial resistance (AMR) is one of the important topics in the One Health approach. Monitoring and controlling the zoonotic transmission of resistant microorganisms and involving not only medical authorities but also veterinarians, farmers, food safety experts, ecologists, and zoologists in this process are essential aspects of this approach.

In order to address the issue of AMR (Antimicrobial Resistance) in animal health, the World Health Organization (WHO) has developed Global Action Plans that envisage optimizing the use of antimicrobials. It has encouraged each country to create a National Action Plan. In addition to WHO, the Food and Agriculture Organization (FAO) has also developed strategies and action plans with the same purpose.

In our country, a surveillance network has also been established for the issue of AMR (Antimicrobial Resistance), and in 2011, the National Antimicrobial Resistance Surveillance System (UAMDSS) was established under the auspices of the General Directorate of Public Health. This system is part of the "Central Asian and Eastern European Antimicrobial Resistance Surveillance Network (CAESAR)" led by the WHO European Office and operates on the same principles[32]. As part of the One Health approach in the field of veterinary medicine to combat AMR, the Ministry of Agriculture and Forestry has prepared an "Action Plan for Antimicrobial Resistance Monitoring and Control in Veterinary Medicine[33].

Dentists' Attitudes and Approaches to Antibiotic Prescription

The increasing use of antibiotics poses a serious global threat in terms of bacterial resistance, and dentists contribute significantly to the development of this threat. Antibiotics are often misused in various ways, such as incorrect dosages, regimens, and treatment durations. In some dental patients, even though the likelihood of developing bacterial infections is low, antibiotics are prescribed unnecessarily, and these antibiotics are used for extended periods and in broad-spectrum forms without a valid reason. Several studies have shown that dentists do not always adhere to guidelines when prescribing antibiotics due to unnecessary antibiotic prescriptions (overuse) or inappropriate antibiotic prescriptions (misuse)[34]. In a study conducted by

Kleva and colleagues on 154 dentists working in a university hospital and private clinics in Albania, it was found that 37% of participating dentists made incorrect prescriptions and applied incorrect dosage regimens when attempting to rationalize antibiotic prescriptions[35].

In another study that examined the knowledge, attitudes, and behaviors of dentists regarding rational antibiotic use, it was observed that 70% of participating dentists based their prescriptions on the National Essential Medicines List before writing a prescription. However, the same participants found that 15% of them prescribed antibiotics for odontogenic pain treatment, and 30% of them incorrectly accepted the statement "There is no problem for a patient with amoxicillin allergy to use cephalosporin" as true[36]. These results indicated that the participants lacked sufficient knowledge about antibiotic usage indications and the concept of cross-allergy.

In a comprehensive study conducted in our country, which analyzed nearly nine million prescriptions, it was found that less than 4% of the prescriptions contained antibiotics written with logical justifications (for cellulitis and oral abscesses)[37]. In one-fifth of the prescriptions in the study, "dental examination" was entered as the reason for antibiotic prescription, which was considered an invalid indication. Spiramycin, amoxicillin, cephalexin, fusidic acid, and cefaclor were the most commonly prescribed antibiotics, and the fact that they were prescribed more for dental caries than cellulitis and oral abscesses was the most prominent indicator of irrational antibiotic prescribing.

In a study investigating irrational drug use, it was mentioned that there are postgraduate education deficiencies among healthcare professionals regarding rational antibiotic use, and sometimes they resort to prescribing antibiotics due to feeling pressure from patients[38].

In addition to healthcare professionals who prescribe antibiotics with incorrect and unnecessary indications in irrational drug use, patients also play a significant role due to their inadequate or incorrect knowledge, attitudes, and behaviors. In the study by Akıcı et all[39], a considerable proportion of patients were found to use antibiotics before seeking medical attention for indications that are limited in the field of dentistry and should only be used under a healthcare professional's supervision (29.3%). This is an example of the importance of irrational drug use and can be considered one of the fundamental reasons for the problem of antibiotic resistance.

In the era of antibiotic resistance, rational antibiotic use is being attempted to be controlled through the implementation of global and national action plans. However, it may help to reduce the resistance weapon in the microorganism-host battle if dentists periodically participate in postgraduate training and update treatment protocols by following accepted guidelines. The importance of the One Health approach in antibiotic use should be recognized, and all sources that can contribute to antibiotic resistance in our ecosystem (human-animal-environment) should be monitored for resistance and controlled through surveillance networks.

REFERENCES

1. Pokharel, S., Shrestha, P. & Adhikari, B. (2020), Antimicrobial use in food animals and human health: time to implement 'One Health' approach. *Antimicrob Resist Infect Control* 9, 181, https://doi.org/10.1186/s13756-020-00847-x
2. Tamma, P.D., et al. (2017), Association of adverse events with antibiotic use in hospitalized patients, *JAMA Internal Medicine*,. 177(9), 1308-1315.
3. Sukumar, S., Roberts, AP., Martin, FE., Adler, CJ. (2016), Metagenomic Insights into Transferable Antibiotic Resistance in Oral Bacteria, *J Dent Res*, 95(9):969-976. doi:10.1177/0022034516648944
4. Fernandez-Canigia, L., Cejas, D., Gutkind, G., & Radice, M. (2015). Detection and genetic characterization of beta-lactamases in Prevotella intermedia and Prevotella nigrescens isolated from oral cavity infections and peritonsillar abscesses. *Anaerobe*, 33, 8–13. https://doi.org/10.1016/j.anaerobe. 2015.01.007
5. Sedgley, C. M., Lee, E. H., Martin, M. J., & Flannagan, S. E. (2008), Antibiotic resistance gene transfer between Streptococcus gordonii and Enterococcus faecalis in root canals of teeth ex vivo, *Journal of Endodontics*, 34(5), 570– 574. https://doi.org/10.1016/j.joen.2008.02.014
6. Palmer, N. (2020), Antimicrobial prescribing in dentistry: Good practice guidelines (3rd ed.), *Faculty of General Dental Practice (UK) and Faculty of Dental Surgery*
7. Chaffanel, F., Charron-Bourgoin, F., Libante, V., Leblond-Bourget, N., & Payot, S. (2015), Resistance genes and genetic elements associated with antibiotic resistance in clinical and commensal isolates of Streptococcus salivarius, *Applied and Environmental Microbiology*, 81(12), 4155–4163. https://doi.org/10.1128/AEM.00415-15
8. Çöleri, A., Çökmüş, C. (2008), Molecular Mechanisms of Resistance to Glycopeptide Antibiotics in Enterococcus Species and Modes of Gene Transfer. *Türk Hijyen ve Deneysel Biyoloji Dergisi*, 65 (2): 87-96
9. Alpaslan, C. (2008), Diş Hekimliğinde Sık Kullanılan İlaçlar
10. Natarajan, S. (2004), Antibiotic treatment for odontogenic infections, *Canadian Pharmaceutical Journal*, 137(10), 25–29.
11. Llison, SJ. (2009), The role of phenoxymethyl penicillin, amoxicillin, metronidazole and clindamycin in the management of acute dentoalveolar abscesses-a review, *Br Dent J*, 206(7), 357-62.
12. Baumgartner, JC. (2006), Antibiotics and treatment of endodontic infections. *American Associations of Endodontics, Colleagues for Excellence Newsletters*, 2:1-6.
13. Bush, K. (2010), β-Lactam antibiotics: penicillins, *In: Finch RG, Greenwood D, Ragnar Norrby S, Whitley RJ, eds. Antibiotic and Chemotherapy. 9thed. Edinburgh; New York: Saunders Elsevier*, 200-25.
14. Canoğlu E., Güngör H. C. (2009), Çocuk Diş Hekimliğinde ilaç Kullanımı, *Hacettepe Diş Hekimliği Dergisi*, 33(2), 30-44.

15. Schleiss, MR.(2007), Principles of antibacterial therapy. Part XVI: Infectious diseases, Section 3; Antibiotic therapy, Chapter: 179, *In: Kliegman RM, Behrman RE, Jenson HB, Stanton BF, eds. Nelson Textbok of Pediatrics. 18thed. Philadelphia: Saunders,* 1113-8.

16. Chambers, HF., Petri, WA. (2001), Section: VIII: Chemotherapy of microbial diseases. *In: Hardman JG, Limbird LE, Gilman AG, eds. Goodman Gilman's the Pharmacological Basis of Therapeutics. 10thed. United States: Mc Graw Hill Companies*, 1141-271.

17. Aydın, K. (2007), Makrolidler ve Linkozamidler, *ANKEM Derg*, 21, 57-61.

18. Gilbert, DN., Moellering, RC., Eliopoulos, GM., Chambers, HF., Saag, MS. (2013), Dosages of antimicrobial drugs in adult patients with renal impairment. *In: Gilbert DN, Moellering RC, Eliopoulos GM, Chambers HF, Saag MS, eds. The Sandford Guide to Antimicrobial Therapy. 43rd ed. USA: Antimicrobial Therapy, Inc,* 204-13.

19. Baltacıoğlu, E., Akalın, A. (2006), Tetracyclines and their non-antimicrobial properties. A new approach to their use in periodontal treatment, *Hacettepe Dişhekimliği Fakültesi Dergisi,* 30(1), 97-107.

20. Honibald, EN., Mathew, S., Padmanaban, J., Sundaram, E., Ramamoorthy, RD. (2012), Perioceutics: matrix metalloproteinase inhibitors as an adjunctive therapy for inflammatory periodontal disease, *J Pharm Bioallied Sci*, 4, 417-21.

21. Akca, G., Kayaoğlu, G., Akca, AE., Sultan, N. (2010), Viridans streptococci isolated from dentin caries and their susceptibilities to common and new generation antibiotics, *GÜ Diş Hek Fak Derg*, 27, 187-93.

22. Termine, N., Panzarella, V., Ciavarella, D., ve Muzio, L. (2011), Antibiotic prophylaxis in dentistry and oral surgery: Use and misuse Intellidrug View project Infectious diseases and chronic hepatitis in immigrants View project, *Article in International Dental Journal*, 59, 263–270.

23. Morrow, SG. (2012), Use and abuse of antibiotics. American Association of Endodontics, *Colleagues for Excellence Newsletter*, 4:1-8.

24. Nishimura, R. A., Otto, C. M., Bonow, R. O., Carabello, B. A., Erwin, J. P., Guyton, R. A., O'Gara, P. T., Ruiz, C. E., Skubas, N. J., Sorajja, P., Sundt, T. M., ve Thomas, J. D. (2014), 2014 AHA/ACC guideline for the management of patients with valvular heart disease: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines, *Journal of the American College of Cardiology*, 63(22).

25. Akal, N. (1998), Antibiotics in pediatric dentistry, *GÜ Diş Hek Fak Derg,* 15(1-2-3), 163-72.

26. Akıcı, N, Başaran NF. (2015), Rational use of medicine in children, *Turkiye Klinikleri J Pharmacol-Special Topics*, 3(1):5

27. Slots, J. (2004), Research, Science and Therapy Committee. Systemic antibiotics in periodontics, *J Periodontol*, 75(11):1553-65.

28. Bahrani-Mougeot FK., Paster, BJ., Coleman, S., Ashar, J., Barbuto, S., Lockhart, PB. (2008), Diverse and novel oral bacterial species in blood following dental procedures, *J Clin Microbiol* 46(6):2129-32.

29. Savadi, N., Barati, O., Mirhadi, H., ve Golkari, A. (2019), Designing a customized clinical practice guideline regarding antibiotic prophylaxis for Iranian general dentists, *BMC Oral Health*, 19(1).

30. Lockhart, P. B., Tampi, M. P., Abt, E., Aminoshariae, A., Durkin, M. J., Fouad, A. F., Carrasco-Labra, A. (2019), Evidence-based clinical practice guideline on antibiotic use for the urgent management of pulpal- and periapical-related dental pain and intraoral swelling, *The Journal of the American Dental Association*, 150(11), 906– 921.e12. doi:10.1016/j.adaj.2019.08.020

31. Süzük, SY., Kaskatepe, B., Ünaldı, Ö., et al. (2021), Tek sağlık yaklaşımında multidisipliner uygulamalı antibiyotik duyarlılık testi eğitimi: Anadolu projesi, *Turk Mikrobiyol Cemiy Derg,* 51(4):341-7.

32. Yıldız, S.S., Şimşek, H., Çöplü, N., Gülay, Z., UAMDSS Çalışma Grubu. (2017), "Ulusal Antimikrobiyal Direnç Sürveyans Sistemi (UAMDSS) Dış Kalite Değerlendirme Çalışmaları: 2011-2016 National Antimicrobial Resistance Surveillance System (NAMRSS) External Quality Assessment Studies: 2011-2016", *Mikrobiyoloji Bülteni*, 51(3): 247-259

33. Gıda ve Kontrol Genel Müdürlüğü (2018-2023), Antimikrobiyal Direnç Önleme Stratejik Eylem Planı Önceliklendirilme ve Maliyetlendirme Aracı Geliştirilmesi Çalıştayı, https://www.tarimorman.gov.tr/GKGM/ Haber/274/Antimikrobiyal-Direnc-Onleme-Stratejik-Eylem-Plani-Onceliklendirilme-Ve-Maliyetlendirme-Araci Gelistirilmesi-Calistayi

34. Löffler, C., Böhmer, F. (2017), The effect of interventions aiming to optimise the prescription of antibiotics in dental care-a systematic review, *PLoS One,* ;12, 0188061.

35. Kleva, S., Elona, K., Edit, X., Anis, T., Neada, H., Suida, K. (2022), Approach to the Current Rational Use of Antibiotics among the Albanian Dentist Community, *J Pharm Bioallied Sci*, 14(2),106-113. doi:10.4103/jpbs.jpbs_243_22

36. Pisarnturakit, PP., Sooampon, S., Sooampon, S. (2020), Managing knowledge for health care quality: An investigation of rational antibiotic use among Thai dentists, *Int J Health Plann Manage*, 35(2), 606-613. doi:10.1002/hpm.2971

37. Koyuncuoglu, C.Z., Aydin, M., Kirmizi, N. *et al.* (2017), Rational use of medicine in dentistry: do dentists prescribe antibiotics in appropriate indications?, *Eur J Clin Pharmacol* **73**, 1027–1032 https://doi.org/10.1007/s00228-017-2258-7

38. Alay, H., Kesmez, Can F., Kaya, Z., Uçar, M. (2021), Akılcı antibiyotik kullanımı konusunda aile hekimlerinin bilgi ve yaklaşımlarının değerlendirilmesi, *Turkish Journal of Clinics and Laboratory*, 3, 235-241.

39. Akıcı, A., Koyuncuoğlu, C.Z., Kırmızı N.İ., Ceylan, İ. (2017), Investigation of Patients' Attitudes Regarding Drug Use Before Application to Dental Clinics, *Marmara Pharmaceutical Journal*; 21(1), 165-176.

CHAPTER 3

PRIMARY DENTITION AND EARLY CHILDHOOD CARIES

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INTRODUCTION

One of the integral elements of general health is oral and dental health. The term health is a holistic and comprehensive concept. Diseases and disorders related to oral and dental health affect the quality of life of individuals in every period and field of their life cycle (Vishwanathaiah, 2016). Tooth decay is one of the most common oral and dental health problems. Dental caries, which is an important public health problem, can be seen at all ages worldwide and is one of the most common chronic diseases in childhood and adolescence (Selwitz et al., 2007). According to the World Health Organization (WHO), the prevalence of caries in the primary dentition ranges from 60% to 90% worldwide (Petersen et al., 2005; Innes et al., 2013). Early childhood caries (ECC), as a result of the imbalance between protective factors and risk factors, it is the most common oral and dental health problem in the primary dentition process (Ismail & Sohn, 1999). This situation, which is encountered in milk teeth, increases the risk of developing caries in permanent teeth in the future (Lynch, 2013). For this reason, it is one of the main goals of pediatric dentistry to preserve the deciduous teeth in a healthy oral environment until the permanent teeth erupt (Akçay & Sarı, 2012).

Primary Dentition

Primary teeth begin their development in the intrauterine period (Brecher & Lewis, 2018). The primary dentition period begins with the eruption of the mandibular anterior incisors, that is, the first primary teeth, in the 6th month after birth, and ends with the eruption of the permanent first molars around the age of 6 years. Primary incisors begin to erupt when babies are approximately 6-12 months old. Generally, the first primary molars last around 1 year, and the second primary molars last around 2 years. The eruption of primary teeth is completed at approximately 2.5-3 years of age. There are a total of 20 deciduous teeth in the oral cavity, ten in the maxilla and ten in the mandibula. Permanent first molars begin to erupt from the back of the primary teeth as of the age of 6, and at this age, the mixed dentition period, in which milk and permanent teeth are seen together, begins. This period generally covers the age range of 6-13 years (Nelson & Ash, 2010; Hulland et al., 2000; Çayönü et al., 2020; Akgün et al., 2011).

The eruption of teeth, called teething, is a natural and physiological process. Most of the time, this period is easily overcome with little or no problems. However, some infants may experience systemic effects such as moodiness, sleep disturbances, decreased appetite, mild fever, and skin rashes during this period. In addition to these, there are some local effects of this period such as itching of the gums, increased salivation and mild redness around the mouth (Brecher & Lewis, 2018; Macknin et al., 2000). Many pharmacological and non-pharmacological strategies exist to alleviate or eliminate these symptoms. Systemic or topical analgesic use, antibiotic use, massaging the gingival ridges and using a teething ring are some of these methods (Hadadi, 2019).

Although primary teeth and permanent teeth are histologically and morphologically similar to each other, there are some differences between them (Sumikawa et al., 1999). Primary teeth, which have a shorter duration of time in the mouth, are lighter in color than permanent teeth and appear as if they are knotted in the cervical region. The occlusal surfaces of primary molars are narrower in the buccolingual direction. The contacts of primary teeth are in the form of surfaces, not points, and these properties are important in restoration applications (Mutluay & Mutluay, 2016). Primary teeth are smaller than permanent teeth in all dimensions, and the enamel and dentin thickness of primary teeth is approximately half that of permanent teeth. The mineralization rate of primary teeth is lower than that of permanent teeth, and the width of the pulp chambers for all tooth sizes is greater than that of permanent teeth. The pulp horns run closer to the outer surface of the tooth. While the height of the pulp chamber decreases from the first primary molar to the second primary molar in these teeth, the situation is the opposite in permanent teeth (Sumikawa et al., 1999; Carrotte, 2005). In addition, the aprismatic enamel layer is observed to be thicker in primary teeth (Gwinnett, 1967).

Primary teeth have a wide variety of functions. First of all, primary teeth help children's chewing and biting functions, take part in their growth and development by facilitating their feeding, and help the development of phonation by supporting the development of the jawbone and facial muscles (Lynch, 2013; Akgün et al., 2011). At the same time, since the teeth in the anterior region are important in terms of aesthetics, it also affects children psychologically in case of deficiency (Usha et al., 2007). In addition to all these, one of the most important tasks of primary teeth is to hold space for the permanent teeth underneath and to guide them in the eruption phase of these teeth (Lynch, 2013). As a result of early loss of primary teeth due to trauma or caries, loss of space in the arch and unwanted tooth movements can be seen, and orthodontic problems may be encountered in later ages (Lin et al., 2011). Due to early loss of primary teeth, the risk of encountering malocclusions such as ectopic eruption, midline shift and crowding problems increases during the permanent dentition period. For this reason, it is aimed to keep primary teeth in the mouth; however, if there is early tooth loss for any reason, these problems can be prevented with the use of appropriate space maintainers (Law, 2013; Gök & Kırzıoğlu, 2016).

Caries in Primary Teeth

Tooth decay is explained as a multifactorial, contagious, chronic and infectious disease characterized by acid derivative compounds that colonize the tooth surface and ferment carbohydrates from cariogenic bacteria in plaque, and demineralize the hard tissues of the tooth over time (Touger-Decker & Van Loveren, 2003). Cariogenic bacteria, fermentable carbohydrates, caries-prone host and time factors are the four main components that play a role in the etiology of caries (Harris et al., 2004).

Since the content and structure of primary teeth differ from permanent teeth in many features, the rate of progression and incidence of caries lesions in primary teeth is higher than in permanent teeth (Sumikawa et al., 1999). In primary teeth, enamel and dentin tissues are thinner than permanent teeth, there are wider dentinal tubules, the pulpal repair mechanism is reduced over time, the mineralization content of primary teeth is lower than permanent teeth, and the pulp horns in primary teeth are closer to the outer surface of the tooth. factors cause the infection to spread more rapidly (Sumikawa et al., 1999; Carrotte, 2005).

Early Childhood Caries

ECC is a special form of dental caries observed early in life in infants and young children. ECC is defined as a chronic, infectious and irreversible disease with many etiological factors (Qin et al., 2008; Thitasomakul et al., 2006). ECC is explained as the presence of one or more decayed teeth (carious lesions with or without cavitation), a tooth lost due to caries, or a tooth filled due to caries, in any primary tooth in children 71 months of age and younger. Severe early childhood caries (S-ECC) are any caries on the flat surfaces of the teeth in children younger than 3 years of age, more than 4 or 4 caries at 3 years of age, more than 5 or 5 caries at 4 years of age, more than 6 or 6 caries at 5 years of age, It is explained as missing teeth and finding filled teeth (Ismail, 2003; American Academy of Pediatric Dentistry, 2020).

Prevalence of Early Childhood Caries

It is stated that the prevalence of ECC can vary between 3% and 74% worldwide (American Academy of Pediatric Dentistry, 2016). In their study in Turkey by Eronat and Koparal in which they examined the prevalence of caries in 500 Turkish children aged between 2 and 13 years, the prevalence was reported as 34.6% for this age group (Eronat, & Koparal, 1997). In a study by Kuvvetli et al. examining the prevalence of caries in 300 5-year-old Turkish children, the prevalence for children in this age group was reported as 45.7% (Kuvvetli et al., 2008). Even within the borders of the same country, prevalence values may differ due to various risk factors (Kim Seow, 2012). Factors such as race, culture, socioeconomic level, lifestyle, dietary habits, and oral hygiene habits may affect the prevalence of ECC (Congiu et al., 2014).

Clinical Evaluation of Early Childhood Caries

ECC begins as white spot lesions along the gingival line of the labial surfaces of maxillary incisors and appears as chalky, opaque, decalcified areas. In its further stages, it spreads to the occlusal and buccal surfaces of the maxillary and mandibular primary molars, and to the vestibule surfaces of the primary canines. The mandibular incisors are rarely affected, but most of the time they are not. With the progression of decalcified lesions, the surface integrity of the enamel tissue deteriorates and cavitation occurs. These cavities can turn yellow, brown or black over time. With further progression of the lesion, hard tissue destruction accelerates. This can make the tooth unstable and cause crown fractures (Tinanoff & O'Sullivan, 1997; Misra et al., 2007). The teeth most affected by ECC are the maxillary incisors. The mandibular incisors, on the other hand, mostly remain intact due to their physical protection by the tongue and the washing properties of the saliva secreted from the salivary glands in the mandibula (Tinanoff & O'Sullivan, 1997).

Etiology of Early Childhood Caries

AAPD explains ECC as a chronic and infectious disease that develops when there is an imbalance between risk factors and protective factors. A wide variety of risk factors play a role in the occurrence of ECC, which has a multifactorial nature (American Academy of Pediatric Dentistry, 2020).

Microbiological Risk Factors

The development process of caries lesions begins with the combination of host, fermentable carbohydrate foods, time and cariogenic microorganism factors. Streptococcus mutans (S. mutans) and Streptococcos sobrinus are the main microorganisms responsible for the onset of dental caries in children and adults. Microorganisms responsible for the progression of caries are known as Lactobacillus acidophilus and Lactobacillus casei ((American Academy of Pediatric Dentistry, 2020; Çehreli, 2015). The newly identified S. wiggsiae and S. mutans, which are known to be responsible for caries onset, are currently reported as pathogens responsible for the development of S-ECC (Tanner et al., 2011).

S. mutans transmission can occur in two different ways. The first of these is the vertical transmission of S. mutans to the baby by the mother or caregiver. This transition occurs for reasons such as kissing the baby on the lips, cleaning the baby's spoon or pacifier in the mouth of the mother or caregiver (Dasanayake & Caufield, 2002). In a study evaluating the relationship between S. mutans levels in mothers and their babies, it was reported that there is a significant relationship between S. mutans levels in the oral environment of the mother and baby (Brown et al., 1985). The other route of transmission is horizontal transmission from other members of the family, such as siblings or friends, peers (Dasanayake & Caufield, 2002). Mattos-Graner et al. (Mattos-Graner et al., 2001) isolated S. mutans from 12-30 month-old nursery children in Brazil, and as a result reported that S. mutans with a similar genotype was present in most of the children. Cariogenic microorganisms generally pass from infected individuals to infants during the period defined as the "infectivity window" between 19-31 months. However, it has recently been reported that this can occur in earlier periods, even before the eruption of teeth (Dasanayake & Caufield, 2002; Caufield et al., 1993).

Dietary Risk Factors

Carbohydrates such as sucrose, fructose, glucose, which can be fermented by cariogenic microorganisms, are one of the important factors in the development of dental caries. Fermentable carbohydrates cause the formation of a suitable substrate for bacteria. It is one of the most important caries factors, especially since it is involved in sucrose, extracellular polysaccharide and intracellular polysaccharide synthesis (Newbrun, 1967; Paes Leme et al., 2006). Frequency of carbohydrate consumption and exposure time of teeth to fermentable carbohydrates are very important risk factors in the formation of dental caries. The neutralization of the organic acid formed after the metabolization of sugar in the oral cavity or its removal from the saliva occurs in the range of 20-40 minutes (Douglass et al., 2004). For this reason, frequent sugar consumption and long stay of sugar in the oral cavity increase the risk of loss of mineralization in the teeth (Douglass et al., 2004; Tinanoff & Palmer, 2000). Especially between meals, before and during sleep due to decreased salivary flow, its protective feature decreases and accordingly the risk of demineralization in dental tissue increases (Qin et al., 2008; Misra et al., 2007).

It is recommended that infants be breastfed during the first 24 months of life (Topal et al., 2017). In addition to the many benefits of breast milk that affect general health, its relationship with ECC has not been clarified. Some studies have reported that breastfed children are less likely to be affected by ECC (dos Santos & Soviero, 2002; Schroth et al., 2005). The reason for this is shown to be that breast milk contains antibacterial agents against cariogenic microorganisms, phosphoproteins in breast milk prevent tooth hard tissue loss, and because breast milk contains calcium and phosphate, it protects dental tissue by minimizing demineralization and supporting remineralization (Nakayama & Mori, 2015). In some studies, it has been reported that there is a risk of developing ECC in children who are breastfed for longer than 12 months (Hallett & O'Rourke, 2002; Tsubouchi et al., 1995). It has been reported that breastfeeding of infants at night increases the prevalence of ECC (Hallett & O'Rourke, 2002; Hallonsten et al., 1995). Prolonged breastfeeding during the day or especially during the night or the use of formula with breast milk has been shown to be a risk factor for ECC (American Academy of Pediatric Dentistry, 2020).

Along with frequent feeding at night, giving the child foods that will support the development of dental caries, giving sweetened milk or cariogenic drinks with a bottle, and using pacifiers sweetened with sugary foods such as honey or molasses are some of the important risk factors for ECC (Ripa, 1988). With the use of bottles during the night, saliva flow and the buffering capacity of saliva decrease, the bottle or teat prevents the contact of saliva with dental hard tissues and increases the contact time of cariogenic nutrients to the teeth (Tyagi, 2008; Feldens et al., 2012; Bowen & Lawrence, 2005).

Host-Related Risk Factors

There are many host-related risk factors that increase the susceptibility of teeth to caries lesions. Various immunological factors, presence of some defects in enamel tissue, morphological features of teeth, genetic characteristics associated with teeth, presence of crooked teeth in the oral cavity, decreased salivary flow rate and buffering capacity are some of these risk factors (Seow, 1998).

Many studies have shown that there is a serious relationship between developmental defects of teeth and dental caries. Premature birth, low birth weight, presence of systemic disease, various nutritional problems, and prenatal or postnatal infections/diseases can cause many developmental disorders such as enamel defects. Although these developmental disorders are risky in terms of plaque involvement, they increase the sensitivity of teeth to caries (Seow, 1998; Davenport et al., 2004). The presence of developmental defects such as hypolasia in dental tissues is considered a serious risk factor for ECC (Davies, 1998). Studies have reported that there is a relationship between S. mutans levels and enamel hypolasia (Li et al., 1994).

Regardless of the infections causing enamel hypoplasia, the prevalence of caries seems to be high in children with asthma receiving medical treatment. In a study in children with bronchial asthma, it was reported that the use of beta-2 agonist powder inhalers and oral medications containing sugar are a predisposing factor for the development of ECC (Reddy et al., 2003). Likewise, obese children are also at risk for ECC. Due to bad and irregular eating habits, which is the common aspect of dental caries development and obesity, these patients should be kept under regular control (Güven Polat et al., 2012).

Today, it is argued that genetic factors are also effective in the development of dental caries. It is stated that some genes such as amelogenin, ameloblastin, tuftelin 1 and enamelin, which are involved in the formation and development of enamel, are effective in caries sensitivity (Patir et al., 2008).

Other Risk Factors

Many factors affect ECC, including social, cultural, ethnic, behavioral and economic conditions (Davies, 1998). While factors such as sex, ethnicity, and age are among the natural risk factors in ECC observation; Factors such as place of residence, education level, occupation, income level are stated among acquired risk factors (Ansari et al., 2003). At the same time, the presence of plaque in the child, whether the fluoride intake is sufficient, and the number of missing teeth of the mothers are among the risk factors (Alaki et al., 2008).

In many studies, the socioeconomic status of the parents is associated with the oral and dental health of their children. In addition to low birth weight in children of parents with low socioeconomic status, the presence of ECC is a common finding in most studies (Fisher-Owens et al., 2007; Tiwari et al., 2014). Campus et al. (Campus et al., 2004) reported that the risk of ECC is higher in children from low-income families, as a result of their study evaluating the oral and dental health of 418 kindergarten children aged 2.5-6.5 years in Italy.

The education level of the family is also an effective factor on the oral and dental health of children. It has been reported that parents with a high level of education are more likely to benefit from preventive treatment approaches (Kuşgöz & Aydınoğlu, 2016). In a study, it was shown that the prevalence of caries and dmf-t values were low in children aged 18-72 months, whose parents had a high level of education (Stephen et al., 2015).

Early Childhood Caries Prevention Methods

Epidemiological data report that preventive and preventive approaches are more ideal than restorative treatments in the management of caries observed in early childhood with multifactorial etiology (Patır Münevveroğlu et al., 2014). The general approach to the prevention of ECC is to eliminate risk factors (Kowash et al., 2000). Precautions to be taken to prevent ECC risks should be started in the prenatal period. It is stated that many factors such as regular dental visits of the mother, oral hygiene practices and appropriate prenatal dietary habits are approaches to reduce the risk of ECC (Tozar & Erkmen Almaz, 2021; Xiao et al., 2019). At the same time, in order to prevent transmission of S. mutans, parents should be made aware of issues involving saliva sharing, such as not using the same plates or spoons as their children, whether to clean the child's bottle or pacifier with their own saliva, and not to kiss their children on the lips (Misra et al., 2007; Berkowitz, 2003).

It is very important to increase the awareness of parents in terms of oral hygiene habits, nutrition and fluorine applications in establishing an ideal oral and dental health in children in the postnatal period (Kowash et al., 2000). In terms of minimizing the risk of caries, reducing the frequency of feeding with bottles, which are sugary foods in babies, not keeping the oral environment clean after bottle feeding, reducing the use of bottle by the age of 1 and encouraging the use of glasses, reducing the consumption of sugary foods in between meals, and avoiding sugar-containing foods such as honey or molasses on pacifiers. care needs to be taken (American Academy of Pediatric Dentistry, 2020; Gupta et al., 2013). Regular visits to the dentist are also important in order to improve and protect oral and dental health. The AAPD recommends children's first dental visit within 6 months after the first primary tooth erupts or when the baby is 12 months old (American Academy of Pediatric Dentistry, 2020; Misra et al., 2007). In the process after the baby is born, it is an issue that parents should pay attention to, that the inside of the mouth, especially the gums of the baby, should be wiped with a clean cloth after each feeding until the teeth erupt (Çubukçu, 2007; Yılmaz İlgen & Çoğulu, 2018). Soft brushes for children are preferred because they cause less gum trauma. Finger brushes are recommended in oral hygiene applications of newborn babies due to the advantage of applying comfortably without traumatizing teeth and gums (Ulusoy, 2010). With the eruption of the baby's first primary tooth, the parents should start brushing at least 2 times a day with the help of an appropriate amount of fluoride toothpaste with anti-caries effect and a soft toothbrush (Douglass et al., 2004; Toumba et al., 2019).

Treatment Approaches in Early Childhood Caries

There are many factors in the treatment approaches of children with ECC. Although treatment approaches are specific for each patient; it depends on the child's age, compliance during treatment, the extent of carious lesions, and the cooperative attitude of the parents (Ripa, 1988).

Cavitation can occur rapidly in ECC. If cavitation is observed, there are many restorative material options in the treatment. The selection of fluoride-releasing restoration materials such as glass ionomer cement (CIS) is also recommended as a preventative strategy (Weinstein, 1998). Resin-modified glass ionomer cements (RMCIS) have been developed by adding resin to CIS, and this material has also found use in the treatment of ECC (Qvist et al., 2010). Polyacid modified composite resins, ie compomers, which have better physical properties than CIS but have lower fluoride releasing capacity, are also among the materials frequently used in the treatment of primary teeth (Krämer & Frankenberger, 2007). In addition, stainless steel crowns and various post applications are also recommended for the treatment of primary teeth with excessive substance loss (Innes et al., 2006; Motisuki et al., 2005).

The treatment of ECC may need to be done under general anesthesia in cases where cooperation with the patient cannot be achieved. Various treatments such as tooth extractions, vital pulpotomy applications, glass ionomer, compomer and composite restorations, strip crowns and stainless steel crowns can be performed during general anesthesia (Selvi et al., 2008).

Problems That May Occur When Early Chıldhood Caries are Not Treated

Since primary teeth will exfoliate after a certain period of time, it is a very wrong understanding that not enough attention is paid to the problems that occur in these teeth. Primary teeth are important for children's growth and development periods. Because a large period of growth and development belongs to the primary dentition period. Dental problems that occur in this process negatively affect the growth and development of children (Akgün et al., 2011). Problems in primary teeth can cause pain if left untreated. This situation negatively affects growth and development by causing disruption of chewing and biting functions, restriction of food intake and reduction of sleep time (Prabakar et al., 2016). Early loss of maxillary anterior teeth is observed in young children due to ECC status. Speech problems may also be encountered due to the loss of these teeth in the early period (Casamassimo et al., 2009). ECC can cause bad breath and unaesthetic appearances in children, leading to social exclusion of children and disruptions in their psychological development (Gift et al., 1992; Uribe, 2009).

ECC progresses with the demineralization process of dental hard tissues, causing dental abscesses, facial cellulitis, pain, tooth loss, and malocclusion (Baltacı et al., 2017). If the risk factors of ECC are not eliminated, the severe caries development process seen in the primary dentition is an indicator of the caries lesions that will develop in the permanent dentition (EzEldeen et al., 2015). In addition, it has been reported that the success performance at school decreases and the duration of absenteeism increases in young children whose dental caries treatments are interrupted (Neves et al., 2016). All these negative consequences observed due to ECC negatively affect the oral and dental health-related quality of life of children and their families by creating difficulties in managing the results of ECC (American Academy of Pediatric Dentistry, 2020; Casamassimo et al., 2009). At the same time, it is explained that the situations caused by ECC do not only directly affect children individually, but also have various consequences on the family and society (Baltacı et al., 2017).

CONCLUSION

Today, ECC continues to be an important public health problem. For this reason, it is very important to provide preventive and preventive approaches in the early stages of life. With these measures, the risk of children being affected by ECC, which is an aggressive form of dental caries, can be reduced. A multidisciplinary approach should be taken in the prevention of ECC, which has a multifactorial nature. For this purpose, individuals who take care of the child, starting from the prenatal period, should be informed about the importance of primary teeth and oral-dental health. In this regard, all dentists, medical doctors and other health workers, especially pediatric dentists; It is beneficial in informing the public, improving oral and dental health programs, and distributing information in this direction to more widespread segments.

REFERENCES

A. Kuşgöz, S. Aydınoğlu, "Erken Çocukluk Çağı Çürükleri ve Etiyolojisi: Güncel Literatür Derlemesi," *Selcuk Dent J,* 3(1):39-47, 2016.

A. Patır Münevveroğlu, M. Koruyucu, F. Seymen, "Risk Factors for Early Childhood Caries (ECC) in 2-5 Years Old Children," *J Istanbul Univ Fac Dent,* 48(1):19-30, 2014.

A. Patir, F. Seymen, M. Yildirim, K. Deeley, M.E. Cooper, M.L. Marazita, A.R. Vieira, "Enamel Formation Genes are Associated with High Caries Experience in Turkish Children," *Caries Res,* 42(5):394-400, 2008.

A.P. Dasanayake, P.W. Caufield, "Prevalence of Dental Caries in Sri Lankan Aboriginal Veddha Children," *Int Dent J,* 52(6):438-444, 2002.

A. Stephen, R. Krishnan, M. Ramesh, V.S. Kumar, "Prevalence of Early Childhood Caries and Its Risk Factors in 18-72 Month Old Children in Salem, Tamil Nadu," *J Int Soc Prev Community Dent,* 5(2):95-102, 2015.

A.C.R. Tanner, J.M.J. Mathney, R.L. Kent, N.I. Chalmers, C.V. Hughes, C.Y. Loo, N. Pradhan, E. Kanasi, J. Hwang, M.A. Dahlan, E. Papadopolou, F.E. Dewhirst, "Cultivable Anaerobic Microbiota of Severe Early Childhood Caries," *J Clin Microbiol,* 49(4):1464-1474, 2011.

A.F. Paes Leme, H. Koo, C.M. Bellato, G. Bedi, J.A. Cury, "The Role of Sucrose in Cariogenic Dental Biofilm Formation--New Insight," *J Dent Res,* 85(10):878-887, 2006.

A.I. Ismail, "Determinants of Health in Children and the Problem of Early Childhood Caries," *Pediatr Dent,* 25(4):328-333, 2003.

A.I. Ismail, W. Sohn, "A Systematic Review of Clinical Diagnostic Criteria of Early Childhood Caries" *J Public Health Dent,* 59(3):171-191, 1999.

A.J. Gwinnett, "The Ultrastructure of the "Prismless" Enamel of Permanent Human Teeth," *Arch Oral Biol,* 12(3):381-388, 1967.

A.L. Hallonsten, L.K. Wendt, I. Mejàre, D. Birkhed, C. Håkansson, A.M. Lindvall, S. Edwardsson, G. Koch, "Dental Caries and Prolonged Breast-Feeding in 18-Month-Old Swedish Children," *Int J Paediatr Dent*, 5(3):149-155, 1995.

A.P.P. dos Santos, V.M. Soviero, "Caries Prevalence and risk Factors Among Children Aged 0 to 36 Months," *Pesqui Odontol Bras,* 16(3):203-208, 2002.

A.T. Ulusoy, "Pedodontide Güncel Koruyucu Yaklaşımlar," *Atatürk Üniv Diş Hek Fak Derg,* 3:28-37, 2010.

American Academy of Pediatric Dentistry, "Policy on Early Childhood Caries (ECC): Classifications, Consequences, and Preventive Strategies," *Pediatr Dent,* 38(6):52-54, 2016.

American Academy of Pediatric Dentistry, "Policy on Early Childhood Caries (ECC): Classifications, Consequences, and Preventive Strategies," The Reference

Manual of Pediatric Dentistry, Chicago, Ill.: American Academy of Pediatric Dentistry; 79-81, 2020.

B. Gök, Z. Kırzıoğlu, "Yer Tutucu Apareylerin Oral Biyofilm Oluşumuna Etkisi–Derleme," *Balıkesir Sağlık Bilimleri Dergisi,* 5(2):94-98, 2016.

C. Motisuki, L. Santos-Pinto, E.M.A. Giro, "Restoration of Severely Decayed Primary Incisors Using Indirect Composite Resin Restoration Technique," *Int J Paediatr Dent,* 15(4):282-286, 2005.

C.A. Feldens, E.R.J. Giugliani, Á. Vigo, M.R. Vítolo, "Early Feeding Practices and Severe Early Childhood Caries in Four-Year-Old

Children from Southern Brazil: A Birth Cohort Study," *Caries Res,* 44(5):445-452, 2010.

C.S. Law, "Management of Premature Primary Tooth Loss in the Child Patient," *J Calif Dent Assoc,* 41(8):612-618, 2013.

Ç.E. Çubukçu, "Prenatal Dönemde ve Bebeklikte Ağız ve Diş Sağlığı," *Güncel Pediatri,* 5(2):77-81, 2007.

D.A. Sumikawa, G.W. Marshall, L. Gee, S.J. Marshall, "Microstructure of Primary Tooth Dentin," *Pediatr Dent,* 21(7):439-444, 1999.

D.K. Reddy, A.M. Hegde, A.K. Munshi, "Dental Caries Status of Children with Bronchial Asthma," *J Clin Pediatr Dent*, 27(3):293-295, 2003.

E. Baltacı, Ö. Baygın, F.M. Korkmaz, "Erken Çocukluk Çağı Çürükleri: Güncel Literatür Derlemesi," *Turkiye Klinikleri J Dental Sci*, 23(3):191-202, 2017.

E. Newbrun, "Sucrose, the Arch Criminal of Dental Caries," *Odontol Revy,* 18(4):373-386, 1967.

E.A. Brecher, C.W. Lewis, "Infant Oral Health," *Pediatr Clin North Am,* 65(5):909-921, 2018.

E.S. Davenport, C. Litenas, P. Barbayiannis, C.E.S. Williams, "The Effects of Diet, Breast-Feeding and Weaning on Caries Risk for Pre-term and Low Birth Weight Children," *Int J Paediatr Dent,* 14(4):251-259, 2004.

É.T.B. Neves, R.T. Firmino, M. de França Perazzo, M.C. Gomes, C.C. Martins, S.M. Paiva, A.F. Granville-Garcia, "Absenteeism Among Preschool Children due to Oral Problems," *J Public Health,* 24(1):65-72, 2016.

G. Campus, A. Lumbau, A.M. Sanna, G. Solinas, P. Lugliè, P. Castiglia, "Oral Health Condition in an Italian Preschool Population," *Eur J Paediatr Dent,* 5(2):86-91, 2004.

G. Congiu, G. Campus, P.F. Lugliè, "Early Childhood Caries (ECC) Prevalence and Background Factors: A Review," *Oral Health Prev Dent,* 12(1):71-76, 2014.

G. Güven Polat, S.B. Çehreli, M.E. Taşçılar, Ö.M. Akgün, C. Altun, İ.T. Özgen, "The Oral Health Status of Healthy and Obese Children in a Turkish Population: A Cross-Sectional Study," *Turk J Med Sci,* 42(6):970-976, 2012.

G. Yılmaz İlgen, D. Çoğulu, "Erken Çocukluk Dönemi Çürükleri ve Tedavi Yaklaşımları," *Turkiye Klinikleri J Pediatr Dent-Special Topics,* 4(1):50-55, 2018.

G.N. Davies, "Early Childhood Caries--A Synopsis," *Community Dent Oral Epidemiol,* 26(Suppl 1):106-116, 1998.

H.C. Gift, S.T. Reisine, D.C. Larach "The Social Impact of Dental Problems and Visits," *Am J Public Health,* 82(12):1663-1668, 1992.

J. Prabakar, J. John, D. Srisakthi, "Prevalence of Dental Caries and treatment Needs Among School Going Children of Chandigarh," *Indian J Dent Res,* 27(5):547-552, 2016.

J. Tsubouchi, M. Tsubouchi, R.J. Maynard, P.K. Domoto, P. Weinstein, "A Study of Dental Caries and Risk Factors Among Native American Infants," *ASDC J Dent Child,* 62(4):283-287, 1995.

J. Xiao, N. Alkhers, D.T. Kopycka-Kedzierawski, R.J. Billings, T.T. Wu, D.A. Castillo, L. Rasubala, H. Malmstrom, Y. Ren, E. Eliav, "Prenatal Oral Health Care and Early Childhood Caries Prevention: A Systematic Review and Meta-Analysis," *Caries Res,* 53(4):411-421, 2019.

J.M. Douglass, A.B. Douglass, H.J. Silk HJ, "A Practical Guide to Infant Oral Health," *Am Fam Physician,* 70(11):2113-2120, 2004.

J.P. Brown, C. Junner, V. Liew , "A Study of Streptococcus Mutans Levels in Both Infants with Bottle Caries and Their Mothers," *Aust Dent J,* 30(2):96-98, 1985.

K.B. Hallett, P.K. O'Rourke, "Early Childhood Caries and Infant Feeding Practice," *Community Dent Health,* 19(4):237-242, 2002.

K.J. Toumba, S. Twetman, C. Splieth, C. Parnell, C. van Loveren, N.A. Lygidakis, "Guidelines on the Use of Fluoride for Caries Prevention in Children: An Updated EAPD Policy Document," *Eur Arch Paediatr Dent,* 20(6):507-516, 2019.

K.N. Tozar, M. Erkmen Almaz, "Hamilelikte ve Yeni Doğan Çocuklarda Ağız Diş Sağlığı," *Dent & Med J – R,* 3(1):55-67, 2021.

L.W. Ripa, "Nursing Caries: A Comprehensive Review," *Pediatr Dent,* 10(4):268-282, 1988.

M. Akçay, Ş. Sarı, "Madde Kaybı Fazla Olan Ön Grup Süt Dişlerinde Restoratif Yaklaşımlar," *ADO Klinik Bilimler Dergisi*, 4(3):638-646, 2010.

M. EzEldeen, S. Gizani, D. Declerck, "Long-term Outcome of Oral Health in Patients with Early Childhood Caries Treated Under General Anaesthesia," *Eur Arch Paediatr Dent,* 16(4):333-340, 2015.

M. Qin, J. Li, S. Zhang, W. Ma, "Risk Factors for Severe Early Childhood Caries in Children Younger than 4 Years Old in Beijing, China," *Pediatr Dent,* 30(2):122-128, 2008.

M. Usha, V. Deepak, S. Venkat, M. Gargi M, "Treatment of Severely Mutilated Incisors: A Challenge to the Pedodontist," *J Indian Soc Pedod Prev Dent,* 25(5):34-36, 2007.

M.B. Kowash, A. Pinfield, J. Smith, M.E. Curzon, "Effectiveness on Oral Health of a Long-Term Health Education Programme for Mothers with Young Children," *Br Dent J,* 188(4):201-205, 2000.

M.H. Hadadi, "Parental Knowledge and Practices on Infant Teething," *IJMDC,* 3(6):521-525, 2019.

M.L. Macknin, M. Piedmonte, J. Jacobs, C. Skibinski, "Symptoms

Associated with Infant Teething: A Prospective Study," *Pediatrics,* 105(4):747-752, 2000.

M.S. Mutluay, A.T. Mutluay, "Süt Dişlerinde Restoratif Materyal Seçimi ve Etkileyen Faktörler," *Selcuk Dent J,* 3(3):151-158, 2016.

N. Eronat, E. Koparal, "Dental Caries Prevalence, Dietary Habits, Tooth-Brushing, and Mother's Education in 500 Urban Turkish Children," *J Marmara Univ Dent Fac,* 2(4):599-604, 1997.

N. Krämer, R. Frankenberger, "Compomers in Restorative Therapy of Children: A Literature Review," *Int J Paediatr Dent,* 17(1):2-9, 2007.

N. Tinanoff, C.A. Palmer, "Dietary Determinants of Dental Caries and Dietary Recommendations for Preschool Children," *J Public Health Dent,* 60(3):197-209, 2000.

N. Tinanoff, D.M. O'Sullivan, "Early Childhood Caries: Overview and Recent Findings," *Pediatr Dent,* 19(1):12-16, 1997.

N.P. Innes, D.R. Stirrups, D.J.P. Evans, N. Hall, M. Leggate, "A Novel Technique Using Preformed Metal Crowns for Managing Carious Primary Molars in General Practice - A Retrospective Analysis," *Br Dent J,* 200(8):451-454, 2006.

N.P. Innes, J.E. Clarkson, C. Speed, G.V. Douglas, A. Maguire, "FiCTION Trial Collaboration. The FiCTION Dental Trial Protocol–Filling Children's Teeth: Indicated or Not?," *BMC Oral Health,* 13(25):1-13, 2013.

Ö.M. Akgün, S. Görgülü, C. Altun, "Süt Dişlerinin Önemi ve Erken Çocukluk Çağı Çürükleri," *Smyrna Tıp Dergisi*, 1(10):49-52, 2011.

P. Carrotte, "Endodontic Treatment for Children," *Br Dent J,* 198(1):9-15, 2005.

P. Gupta, N. Gupt, A.P. Pawar, S.S. Birajdar, A.S. Natt, H.P. Singh, "Role of Sugar and Sugar Substitutes in Dental Caries: A Review," *ISRN Dent,* 2013:1-5, 2013.

P. Weinstein, "Public Health Issues in Early Childhood Caries," *Community Dent Oral Epidemiol,* 26(Suppl 1):84-90,1998.

P.E. Petersen, D. Bourgeois, H. Ogawa, S. Estupinan-Day, C. Ndiaye, "The Global Burden of Oral Diseases and Risks to Oral Health," *Bull World Health Organ,* 83(9):661-669, 2005.

P.S. Casamassimo, S. Thikkurissy, B.L. Edelstein, E. Maiorini, "Beyond the dmft: The Human and Economic Cost of Early Childhood Caries," *J Am Dent Assoc,* 140(6):650-657, 2009.

P.W. Caufield, G.R. Cutter, A.P. Dasanayake, "Initial Acquisition of Mutans Streptococci by Infants: Evidence for a Discrete Window of Infectivity," *J Dent Res,* 72(1):37-45, 1993.

R. Harris, A.D. Nicoll, P.M. Adair, C.M. Pine, "Risk Factors for Dental Caries in Young Children: A Systematic Review of the Literature," *Community Dent Health,* 21(1):71-85, 2004.

R. Touger-Decker, C. Van Loveren, "Sugars and Dental Caries," *Am J Clin Nutr,* 78(4):881S-892S, 2003.

R. Tyagi, "The Prevalence of Nursing Caries in Davangere Preschool Children and Its Relationship with Feeding Practices and Socioeconomic Status of the Family," *J Indian Soc Pedod Prev Dent,* 26(4):153-157, 2008.

R.H. Selwitz, A.I. Ismail, N.B. Pitts, "Dental caries," *The Lancet,* 369(9555):51-59, 2007.

R.J. Berkowitz, "Causes, Treatment and Prevention of Early Childhood Caries: A Microbiologic Perspective," *J Can Dent Assoc,* 69(5):304-307, 2003.

R.J. Schroth, P. Moore, D.J. Brothwell, "Prevalence of Early Childhood Caries in 4 Manitoba Communities," *J Can Dent Assoc,* 71(8):567, 2005.

R.J.M. Lynch, "The Primary and Mixed Dentition, Post-Eruptive Enamel Maturation and Dental Caries: A Review," *Int Dent J,* 63(2):3-13, 2013.

R.O. Mattos-Graner, Y. Li, P.W. Caufield, M. Duncan, D.J. Smith, "Genotypic Diversity of Mutans Streptococci in Brazilian Nursery Children Suggests Horizontal Transmission," *J Clin Microbiol,* 39(6):2313-2316, 2001.

S. Çayönü, B.N. Yüksel, Ş. Sarı, "Dişsiz Dönemden Daimi Dişlenme Sürecine Kadar Oklüzyonun Kurulumu," *Turkiye Klinikleri J Dental Sci,* 26(1):110-121, 2020.

S. Hulland, J.O. Lucas, M.A. Wake, K.D. Hesketh, "Eruption of the Primary Dentition in Human Infants: A Prospective Descriptive Study," *Pediatr Dent,* 22(5):415-421, 2000.

S. Misra, J.F. Tahmassebi, M. Brosnan, "Early Childhood Caries--A Review," *Dent Update,* 34(9):556-564, 2007.

S. Selvi, Ş. Kavaloğlu Çıldır, N. Sandallı, "Erken Çocukluk Dönemi Çürükleri: Etiyolojisi, Epidemiyolojisi, Koruyucu Yaklaşımlar ve Tedavisi," *Yeditepe Klinik,* 1:48-55, 2008.

S. Thitasomakul, A. Thearmontree, S. Piwat, O. Chankanka, W. Pithpornchaiyakul, R. Teanpaisan, S. Madyusoh, "A Longitudinal Study of Early Childhood Caries in 9- to 18-Month-Old Thai Infants," *Community Dent Oral Epidemiol,* 34(6):429-436, 2006.

S. Topal, N. Çınar, S. Altınkaynak, "Emzirmenin anne sağlığına yararları," *J hum rhythm,* 3(1):25-31, 2017.

S. Uribe, "Early Childhood Caries--Risk Factors," *Evid Based Dent,* 10(2):37-38, 2009.

S. Vishwanathaiah, "Knowledge, Attitudes, and Oral Health Practices of School Children in Davangere," *Int J Clin Pediatr Dent,* 9(2):172-176, 2016.

S.A. Fisher-Owens, S.A. Gansky, L.J. Platt, J.A. Weintraub, M.J. Soobader, M.D. Bramlett, P.W. Newacheck, "Influences on Children's Oral Health: A Conceptual Model," *Pediatrics,* 120(3):e510-e520, 2007.

S.B. Çehreli, "Erken Çocukluk Çağı Çürüğünde Rol Oynayan Faktörler," *Turkiye Klinikleri J Pediatr Dent-Special Topics,* 1(1):55-59, 2015.

S.J. Nelson, M.M. Ash, "Occlusion," Wheeler's Dental Anatomy, Physiology and Occlusion, 9th Edition, Saunders Elsevier, Chapter 16, 275-307, ISBN: 978-1-4160-6209-7, 2010.

S.M. Alaki, B.A. Burt, S.L. Garetz, "Middle Ear and Respiratory Infections in Early Childhood and Their Association with Early Childhood Caries," *Pediatr Dent*, 30(2):105-110, 2008.

S.S. Kuvvetli, S.K. Cildir, S. Ergeneli, N. Sandalli, "Prevalence of Noncavitated and Cavitated Carious Lesions in A Group of 5-Year-Old Turkish Children in Kadikoy, Istanbul," *J Dent Child (Chic),* 75(2):158-163, 2008.

T. Tiwari, D.O. Quissell, W.G. Henderson, J.F. Thomas, L.L. Bryant, P.A. Braun, J.E. Albino, "Factors Associated with Oral Health Status in American Indian Children," *J Racial Ethn Health Disparities,* 1(3):148-156, 2014.

V. Qvist, A. Poulsen, P.T. Teglers, I.A. Mjör, "The Longevity of Different Restorations in Primary Teeth," *Int J Paediatr Dent,* 20(1):1-7, 2010.

W. Kim Seow, "Environmental, Maternal, and Child Factors Which Contribute to Early Childhood Caries: A Unifying Conceptual Model," *Int J Paediatr Dent,* 22(3):157-168, 2012.

W.H. Bowen, R.A. Lawrence, "Comparison of the Cariogenicity of Cola, Honey, Cow Milk, Human Milk, and Sucrose," *Pediatrics,* 116(4):921-926, 2005.

W.K. Seow, "Biological Mechanisms of Early Childhood Caries," *Community Dent Oral Epidemiol,* 26(Suppl 1):8-27, 1998.

Y. Li, J.M. Navia, P.W. Caufield, "Colonization by Mutans Streptococci in the Mouths of 3- and 4-Year-Old Chinese Children with or without Enamel Hypoplasia," *Arch Oral Biol,* 39(12):1057-1062, 1994.

Y. Nakayama, M. Mori, "Association Between Nocturnal Breastfeeding and Snacking Habits and the Risk of Early Childhood Caries in 18- to 23-Month-Old Japanese Children," *J Epidemiol,* 25(2):142-147, 2015.

Y.T. Lin, W.H. Lin, Y.T. Lin, "Twelve-Month Space Changes After Premature Loss of A Primary Maxillary First Molar," *Int J Paediatr Dent,* 21(3):161-166, 2011.

Z. Ansari, N.J. Carson, M.J. Ackland, L. Vaughan, A. Serraglio, "A Public Health Model of the Social Determinants of Health," *Soz Praventivmed*, 48(4):242-251, 2003.

CHAPTER 4

OZONE THERAPY IN DENTISTRY

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INTRODUCTION

Ozone is a naturally occurring compound consisting of three oxygen atoms. It is typically present in the atmosphere, where it serves to filter out harmful ultraviolet rays from the sun. Ozone therapy involves the application of an ozone/oxygen mixture to circulation or body cavities (Sarı, 2022).

This therapy has been utilized in the fields of medicine and dentistry for many years. Ozone gas is utilized medically due to its effects on increasing chronic oxidative stress at the cellular level and its anti-inflammatory, immunomodulatory, anti-hypoxic, wound healing, antimicrobial, metabolism-enhancing, and biosynthesis-promoting properties. Ozone therapy is increasingly recognized as a widely accepted treatment due to its safety, comfort, low cost, and other advantages. It is frequently employed in the treatment of rheumatic, inflammatory, and dental diseases. It has long been employed not only as a radiation shield but also in dentistry, medical laboratories, the destruction of hospital waste chemicals, extending the shelf life of food products through ozonation, purifying city drinking water, purifying pools and fish aquariums, sterilization industries, and veterinary fields (Toprak, 2021).

Given the increasing popularity of ozone therapy as a treatment option in our country, it has become important to conduct various experimental and clinical studies on its efficacy (Boztaş & Ömürlü, 2015). Several studies have reported the utilization of ozone in dentistry for sterilization of dental equipment, dental surgery, treatment of periodontal diseases and some oral pathologies, root canal treatment, and reduction of bacterial levels in active caries to prevent tooth decay. Additionally, some recent studies have suggested the potential use of ozone in tooth whitening (Küçükkolbaşı & Korkmaz, 2013).

Ozone

Ozone (O_3) is a natural compound consisting of three oxygen atoms and represents the energetically higher form of diatomic atmospheric oxygen (O_2). It has a molecular weight of 47.98 g/mol. Despite its chemical structure not being that of a radical molecule, ozone ranks as the third most potent oxidizing agent known after fluorine and persulfate. Ozone is an unstable gas that cannot be stored and has a half-life of approximately 40 minutes at 20°C, requiring immediate use upon generation. It has a sharp odor and a bluish color. Approximately 90% of atmospheric ozone is found within the stratospheric layer, located approximately 20–50 km above the Earth's surface, with the remaining 10% existing within the tropospheric layer, which is located just below the stratospheric layer and ranges between 10 and 15 km in altitude. Ozone in the stratosphere is continuously formed and depleted under the influence of ultraviolet radiation. When an oxygen molecule in the stratosphere encounters high-energy ultraviolet (UV) radiation, it splits into two free oxygen atoms, which subsequently combine with other oxygen molecules to initiate ozone production (Bocci, 2006). Naturally occurring ozone is generated following electrical discharges from lightning storms or ultraviolet radiation emitted by the sun, while it can also be artificially produced using an ozone generator (Nogales CG, Ferrari PH, Kantorovich EO, 2008). Natural ozone plays a vital role in maintaining the biological balance in the biosphere by filtering out ultraviolet rays from the sun. Medical-grade ozone, a powerful oxidizing agent, can be produced in several types of ozone generators (Yamaner, Celakil, & Gökcen Roehlig, 2020). The generation of ozone in medical-grade generators occurs through the following reaction, where pure oxygen passes through an electrical voltage gradient (5-13 mV):

$3O_2 + 68{,}400 \text{ cal} \rightarrow 2O_3$

Ozone generators must be constructed from high-quality, ozone-resistant materials such as stainless steel, neutral glass, and Teflon. Ozone, approximately 1.6 times denser than oxygen and exhibiting a solubility in water one time greater, readily reacts with organic and inorganic molecules dissolved in biological fluids (Bocci, 2006).

Ozone Generation Systems

There are three types of systems used in ozone generation:

1. Ultraviolet System: This system provides low-concentration ozone production by emitting UV light at 185 nm. An oxygen molecule absorbs the low-energy UV light, causing it to break down into atoms. Subsequently, the oxygen atoms react with other oxygen molecules to form ozone. It is used in saunas and for air purification purposes.

2. Cold Plasma System: In this system, an electrostatic field is created between anode and cathode rods through voltage spikes. It is utilized for air and water purification.

Corona Discharge System: This system produces ozone at high concentrations. Insulating spaces are employed to create corona discharge. Consequently, oxygen passing through corona discharge is converted into ozone. This system is easy to use, and the ozone production rate can be controlled. Hence, it is the most preferred system in the fields of medicine and dentistry (Nogales CG, Ferrari PH, Kantorovich EO, 2008).

Mechanism of Action of Medical Ozone

Ozone exhibits various effects including antimicrobial, anti-inflammatory, analgesic, immune stimulant, anti-hypoxic, detoxifying, and bioenergetic effects (Naik, Rajeshwari, Kohli, Zohabhasan, & Bhatia, 2016).

Antimicrobial Effect: Ozone demonstrates its antimicrobial effect by causing damage to the cell membrane. It reacts chemically with the double bonds of hydrocarbons in the cell membrane and also causes modification in the cell content through secondary oxidant effects. Ozone is highly effective against antibiotic-resistant strains. Its antimicrobial activity increases in liquid environments and acidic pH. In viral infections, the primary mechanism of action of ozone involves the sensitivity of infected cells to peroxides and alteration of the activity of reverse transcriptase enzyme by ozone, thereby inhibiting the synthesis of viral proteins (Bocci, 2006).

Immune Stimulant Effect: Ozone affects both cellular and humoral immunity. It stimulates the proliferation of immune system cells and the synthesis of immunoglobulins, while increasing the sensitivity of macrophages to phagocytosis and activating other functions. This activation results in the production of specific molecules called cytokines. This suggests that low-dose ozone application is beneficial in individuals with weakened immune systems or immune disorders. Ozone also increases the synthesis of biologically active molecules such as interleukins, leukotrienes, and prostaglandins, thereby reducing inflammation and promoting wound healing (Bhateja, 2012).

Anti-Hypoxic Effect: Ozone induces changes in cellular metabolism by increasing the partial pressure of oxygen in tissues and oxygen transport in the blood. This change leads to increased utilization of energy sources (glycolysis, krebs cycle, beta-oxidation of fatty acids) due to oxidative respiration. Additionally, it prevents the sedimentation of erythrocytes and increases the contact surface of erythrocytes for oxygen transport. It is important in stimulating circulation disorders and revitalizing organ functions (Saini, 2011).

Analgesic and Detoxification Effect: Ozone causes dilation of arterioles and venules by promoting the release of vasodilators such as nitric oxide (NO).

Effect on Metabolic Rate and Biosynthesis: By stimulating mitochondria and ribosomes, ozone increases intracellular protein synthesis. This change explains the activation of cellular functions and the regeneration potential of tissues and organs (Bhateja, 2012).

During ozone therapy, an increase in the amount of oxygen released to the tissues results in dilation of arterioles and venules. Additionally, it positively affects the defense system and microcirculation. Ozone inactivates bacteria, viruses, fungi, protozoa, and yeasts in various ways. It disrupts the integrity of the cell membrane in bacteria, inhibits cell growth at certain stages in fungi, and damages the viral capsule in viruses, rendering them ineffective (Elvis & Ekta, 2011).

Despite the occurrence of various side effects during ozone application, therapeutic use has been shown to lead to many positive outcomes, especially with the production and dissemination of medical ozone generators. Mechanisms of action have been significantly elucidated due to its increasing use in various fields.

Ozone therapy demonstrates its efficacy by causing oxidation of phospholipids and lipoproteins in the cell membrane in bacteria, inhibiting cell growth factors in fungi, and peroxidizing the viral protein envelope, thereby disrupting the virus-cell interaction. Ozone therapy increases glycolysis rates in red blood cells, leading to stimulation of 2,3-diphosphoglycerate. Stimulation of 2,3-diphosphoglycerate, which regulates the transport and release of oxygen by hemoglobin, leads to increased oxygen delivery to the tissues. Ozone therapy also increases oxidative carboxylation of pyruvate, activating the Krebs cycle and consequently increasing ATP production.

Another mechanism following ozone application involves the initiation of a multifaceted cascade, resulting in the activation of biological responses against moderate oxidative stress. Upon contact with polyunsaturated fatty acids and the liquid portion of plasma, ozone forms hydrogen peroxide (H_2O_2), a reactive oxygen species (Gracer & Bocci, 2005). The resulting moderate oxidative stress activates the transcription factor nuclear factor-erythroid 2-related factor (Nrf2). Activation of Nrf2 enables the antioxidant response, facilitating the clearance of clinically relevant free radicals associated with various diseases (Inal, Dokumacıoglu, Özcelik, & Ucar, 2011).

Medical Ozone Administration Methods

Medical-grade ozone can be applied systemically or locally through methods such as major autohemotherapy, minor hemotherapy, rectal insufflation, as well as intra-articular, intramuscular, intradiscal, subcutaneous, and intracutaneous injection, ozonated water, ozonated oil, oxygen/ozone gas (Nogales CG, Ferrari PH, Kantorovich EO, 2008; Torul, Ayrancı, Ömezli, & Yılmaz, 2021).

Major Autohemotherapy: Major autohemotherapy, the most classic and well-known method of medical ozone application, involves withdrawing a small amount of blood (200–250 ml) from the patient intravenously and mixing it with an appropriate dose of ozone gas for 5–10 minutes before reinfusing it back into the patient. The initial dose of ozone therapy is typically based on achieving a concentration of 15-20 µg/mL, which is considered the threshold for antioxidant activity, with applications ranging between 10-80 µg/mL generally accepted as safe. The treatment often starts at 15-20 µg/mL and gradually increases up to 40 µg/mL based on the patient's age, disease progression, and overall condition. Typically, the treatment is administered twice a week for a total of 10-12 sessions (Bocci, 2006; Korkut, Ayada, & Toru, 2015; Küçükkolbaşı & Korkmaz, 2013).

Minor Autohemotherapy: Minor autohemotherapy involves withdrawing 3-5 ml of blood from the patient intravenously and mixing it with ozone/oxygen at a suitable dose between 10-20 μg/mL before injecting it intramuscularly into the patient. This method, frequently used due to its nonspecific immune-activating effects, is commonly applied in allergic conditions, acne, furunculosis, as well as tendon and ligament injuries (Dıraçoğlu, 2016; Korkut et al., 2015).

Local Application: Beginning with the use of ozone for wound disinfection, this method involves applying ozonated water, oils, and creams to the skin, where they exert their effects by converting into oxygen and oxygen radicals. It is commonly used for burns, wounds, and superficial skin infections (Babucçu, 2011).

Rectal/Vaginal Application: Rectal or vaginal administration of ozone is typically performed in children and adults with vascular issues. In children, ozone-oxygen mixture concentrations between 10-20 μg/mL are applied in volumes of 10-30 ml, while in adults, concentrations between 10-25 μg/mL are applied in volumes of 150-300 ml. Individuals are expected to control the gas for a few minutes after the procedure (Babucçu, 2011).

Direct Injection: Direct injection involves injecting ozone directly into tissues for muscle pain relief, localized fat melting, and intra-articular injection for arthritis and pathological stiffness (Dranguet et al., 2013).

Application Forms of Ozone in Dentistry

Ozonated Water: It has been shown to be effective against gram-positive and gram-negative oral microorganisms, as well as bacteria in plaque biofilm. It is cheaper compared to other chemical irrigation solutions (Goztas, Onat, Tosun, Sener, & Hadimli, 2014). However, it has been demonstrated that ozone in gaseous form is more effective as a disinfectant compared to its aqueous form. It can be preferred in cases where gaseous ozone cannot be used or in addition to gaseous ozone (Azarpazhooh & Limeback, 2008).

Ozonated Oil: It can be obtained by ozonating sunflower, sesame, or olive oil. It has been found effective against Streptococcus, Enterococcus, Staphylococcus, Pseudomonas, Escherichia coli, and especially Mycobacteria, and is recommended for the treatment of fungal infections. Commercially available oils include Oleozone, Bioperoxoil, etc. (Pinna et al., 2001).

Gaseous Ozone: Gaseous ozone can be applied topically with an open system or a sealed suction system to prevent inhalation and associated side effects. Some systems that utilize gaseous ozone include:

- HealOzone (Kavo, Biberach, Germany): It is an air-based system where the gas is applied in a closed circuit. Excess gas is absorbed and neutralized by manganese ions. The concentration of ozone at the tissue interface is 2100 ppm due to the air-tightness of the cap, allowing for safe ozone application (Sousa, Alvim-Ferraz, Martins, & Pereira, 2009).

- Prozone (W&H Dentalwerk, Bürmoos, Austria): Prozone is easy and safe to use as tissue-compatible dosages can be pre-set according to endodontic and periodontal indications. The replaceable plastic attachments (Perio tips or Endo tips) ensure a hygienic environment during pocket gas application (Sousa et al., 2009).

- OzonyTron (MYMED GmbH): The ozone released from the thin tip of the device held to the area to be treated allows ozone application to hard-to-reach areas such as periodontal pockets and root canals. There is no closed circuit in this system (Gupta & Mansi, 2012).

Periodontology and Ozone

The effect of ozone on microorganisms responsible for biofilm formation has been observed in numerous studies, reporting its effectiveness against Actinomyces naeslundii, Veillonella dispar, Fusobacterium nucleatum, Streptococcus sobrinus, Streptococcus oralis, Candida albicans, Streptococcus mutans, Lactobacillus acidophilus, Streptococcus sanguis, Streptococcus salivarius, Porphyromonas gingivalis, Porphyromonas endodontalis, and Aggregatibacter actinomycetemcomitans (Knight, McIntyre, Craig, Mulyani, & Zilm, 2008; Nagayoshi et al., 2004).

It has been observed that ozonated water is effective against gram-positive, gram-negative microorganisms, and C. albicans in dental plaque (Nagayoshi et al., 2004). In addition, it has been observed that ozonated water and distilled water irrigation, applied in addition to scaling and root planing, did not have a significant contribution to the improvement process of halitosis and periodontitis (Eltaş & Yücel, 2013; Habashneh, Alsalman, & Khader, 2015). Furthermore, in studies investigating the contributions of laser and ozone gas, applied in addition to mechanical treatment, to the treatment of chronic periodontitis, no significant difference was found; however, it was reported that the improvement was greater in patients treated with mechanical therapy alone. More studies are needed to express definitive results regarding ozone application.

In a study investigating the effect of ozone on wound healing and epithelialization after periodontal surgery, it was observed that ozone accelerated healing (V. P. Patel, Patel, Kumar, & C., 2013). In another study, ozonated olive oil was applied to the area for the treatment of hypersensitivity after periodontal surgery. The research results showed that the application of ozone together with calcium sodium phosphosilicate was more effective than ozone application alone (P. V. Patel, Kumar, Kumar, Gd, & Patel, 2011).

Researchers also reported that ozone reduced microbial plaque accumulation and was compatible with periodontal cells; however, they emphasized the need for many comprehensive studies on the subject (Sadatullah, Mohamed, & Razak, 2012). Additionally, various studies have shown that ozone has a significant effect in preventing peri-implant mucositis and antimicrobial activities. McKenna et al. and Gerspach et al. evaluated the effects of ozone gas on peri-implant mucositis treatment in their studies. In their study comparing the contributions of subgingival ozone and hydrogen peroxide applications to peri-implant mucositis treatment, McKenna et al. demonstrated that ozone application had a significant benefit in preventing peri-implant mucositis. In the study conducted by Gerspach et al., the bactericidal effect of ozone gas and the cellular response to treatment were examined in preventing peri-implant mucositis, and it was stated that ozone had a significant effect on treatment (Hauser-gerspach, Vadaszan, Deronjic, & Gass, 2012) .

Endodontics and Ozon

Ozone gas is an alternative antiseptic agent in root canal treatment due to its high antimicrobial potency and lack of drug resistance. Ozone has provided 99.9% antibacterial efficacy against the aerobic and anaerobic bacteria in the oral cavity (Elvis & Ekta, 2011).

There are limited studies in the literature regarding the effect of ozone on radicular dentin hardness. An in vitro study conducted at Çukurova University Faculty of Dentistry between October 2020 and January 2021 aimed to compare the effects of photodynamic therapy and ozone gas on root canal dentin hardness with conventional methods. Within the limitations of this in vitro study, it was reported that ozone or photodynamic therapy as disinfection methods may contribute to the hardness of root canal dentin structure (Küden & Karakaş, 2021).

Ozone has great potential in endodontics for use as an antimicrobial agent, irrigation solution, intracanal medicament, and for reducing postoperative pain (Virtej, MacKenzie, Raab, Pfeffer, & Barthel, 2007).

Ozone gas, ozonated water, and ozonized oil have been repeatedly reported for their potential use in endodontic treatment. Ozonated water has been used as an endodontic irrigation solution in many studies and is notable for its effects and benefits. In a study by Cardoso et al., the effectiveness of ozonated water in removing endotoxins, C. albicans, and E. faecalis from root canals was evaluated, demonstrating that ozonated water was effective against both C. albicans and E. faecalis immediately after treatment. However, they reported that ozonated water did not show anti-endotoxin activity (Cardoso & Oliveira, 2008).

Zan et al. investigated the effect of erbium:yttrium-aluminum-garnet (Er:YAG) laser, potassium-titanyl-phosphate (KTP) laser, and ozonated water on E. faecalis in root canals. As a result, they reported that the most effective agent in bacterial removal was 5.25% NaOCl, ozonated water application was more effective than Er:YAG and KTP lasers, and there was no significant difference between the two lasers (Hubbezoglu, Zan, Tunc, & Sumer, 2014).

Çiçek et al. evaluated the reliability of two different apex locators in the presence of different irrigation solutions. The results of this study indicated that irrigation solutions did not have any effect on the reliability of apex locators in detecting the apical foramen (Çiçek & Bodrumlu, 2013).

In a study by Bitter et al., the effect of diode laser (4×10 s, 0.8 W, 980 nm), ozone gas (2×60 s, 100 mL/min), calcium hydroxide [$Ca(OH)_2$], and 1% CHX gel on E. faecalis-infected root canals was compared. It was found that ozone gas removed more bacteria than the diode laser group, and the lowest effectiveness was observed in the group where CHX gel was applied for 1 week (Bitter et al., 2017).

In a study by Tuncay et al., the effect of 40 s of ozone gas and 30 s of photo-activated disinfection (PAD) on the surface hardness of resin-based root canal filling materials was examined. It was reported that the group where ozone gas and AH Plus paste were applied together showed the highest surface hardness in the coronal, middle, and apical thirds of the root canals, and both root canal filling materials with ozone gas application showed the highest surface hardness in their respective groups (Tuncay, Er, Demirbuga, Zorba, & Topcuoğlu, 2016). Reddy et al. compared the effects of ozonated sesame oil, $Ca(OH)_2$, and their combinations as intracanal medicaments on C. albicans. Ozonated oil was found to be more effective in removing C. albicans compared to the other groups (Reddy, Prasad, Sirisha, & Prashanth, 2015).

Pedodontics and Ozon

In a study evaluating the efficacy of ozone combined with remineralizing solution and patient kit in initial fissure caries, it was aimed to support the remineralization process of initial fissure caries, and it was reported that the combined use of ozone therapy with remineralizing solution and patient kit supported the remineralization process of initial fissure caries (Atabek & Öztaş, 2012).

In another study by Çetinkaya et al., the overall clinical success, retention, marginal discoloration, marginal integrity, and caries formation of ClinproTM sealant and Teethmate F-1 fissure sealants with and without ozone therapy were evaluated under in vivo conditions. The study concluded that ClinproTM sealant had higher overall success rates in all observation periods compared to Teethmate F-1, and although not statistically significant, higher overall success rates were reported in the groups treated with ozone therapy (Çetinkaya, Aksoy, & Öz, 2021).

In a study aimed at determining the effectiveness of ozone application in the remineralization cycle before fissure sealant application in initial pit and fissure caries, it was reported that ozone application did not affect the marginal discoloration, marginal adaptation, and retention of fissure sealants and that ozone application turned the demineralization-remineralization cycle of initial caries lesions towards remineralization (Ünal & Öztaş, 2015).

Orthodontics and Ozone

Ozoneized olive oil has been shown to be highly effective in reducing enamel demineralization around brackets during orthodontic treatment (Tiwari, Avinash, Katiyar, Aarthi Iyer, & Jain, 2017).

Restorative Treatment and Ozone

Ozone is a potent and reliable antimicrobial agent. It has strong destructive effects on cariogenic microorganisms. It has been observed that in patients with high caries risk, ozone therapy significantly reduces the progression of caries, provides remineralization, and halts caries development (Almaz & Sönmez, 2015).

In initial studies, root caries lesions have been clinically remineralized with ozone. Additionally, it has been observed in clinical experiences that ozone's non-invasive nature reduces anxiety when compared to traditional treatments (Tahmassebi, Chrysafi, & Duggal, 2014).

In an in vivo study by Holmes comparing ART application with traditional treatments alongside ozone therapy, at the end of an 18-month follow-up period, pulp necrosis was detected in 30% of teeth treated with conventional methods, while this rate was reported as 3% in teeth treated with ozone therapy and ART (V. P. Patel et al., 2013).In a study where Holmes evaluated the effect of ozone application for 10, 20, 30, or 40 seconds on initial pit and fissure caries lesions during 4 and 12 months of follow-up, it was reported that clinically, remineralization occurred by 99% according to DIAGNOdent values (V. P. Patel et al., 2013) .

Nogales et al. have emphasized the need for further studies on the correct timing of ozone application regarding the depth of caries lesions (Nogales CG, Ferrari PH, Kantorovich EO, 2008). Studies have indicated that ozone applications cannot effectively reach the dentin under the enamel, and success is reported to be higher in small lesions compared to larger ones (A. Baysan & Beighton, 2007).

Researchers have reported that the antibacterial effect is higher in small and non-cavitated lesions but weaker in large, cavitated lesions and those close to the dentin and gingiva (Atabek, 2014). It has been concluded that ozone can be applied before acid etching in sealant applications to avoid negatively affecting the physical properties of sound enamel (Celiberti, Pazera, & Lussi, 2006).

Application of ozone gas for 60 seconds after 38% hydrogen peroxide has been reported to reduce sensitivity during tooth whitening procedures and achieve one shade lighter tooth color (AL-Omiri, Hassan, AlZarea, & Lynch, 2016).In conclusion, although tooth whitening with ozone may not be as effective as other methods, it can be used as an alternative due to its lack of sensitivity and use of chemical agents (Sürmelioğlu, Bacaksız, & Özsevik, 2016).

Studies investigating the effect of ozone gas on adhesive systems have yielded different results; while one study found no effect of ozone gas on the bond strength of adhesive material to enamel (Pires, Ferreira, Oliveira, Silva, & Melo, 2013), another study observed that ozone gas reduced microbial adhesion in dentin treated with a self-etch adhesive system (Dalkilic, Arisu, Kivanc, Uctasli, & Omurlu, 2012).

Prosthodontics and Ozone

Plaque accumulation on dentures is particularly rich in C. albicans. Plaque control is important to prevent denture stomatitis. Application of ozonated water can be used to reduce the amount of C. albicans on dentures (Arita et al., 2005).

Ozone usage is also effective in cleaning methicillin-resistant Staphylococcus aureus (MRSA) and viruses. Ozone can be applied to clean the surface of metal frameworks of partial dentures. Direct application of ozone gas increases microbial activity compared to ozonated water. Therefore, ozone gas may be more clinically useful for cleaning removable dentures (Suzuki, Oizumi, & Medical, 1999).

The chemical structures of soft lining materials differ from those of PMMA denture bases, resulting in inconsistent bonding between them. Researchers have applied various treatments such as sandblasting, laser, and maleic anhydride to enhance the bonding between these two materials (Demir et al., 2011; Soygun, Bolayır, & Kapdan, 2013).A study aimed to investigate the effect of ozone application at different durations on the bond strength between PMMA surfaces and soft lining materials reported that the group without ozone application had the highest bond strength, and as the duration of ozone application to PMMA surfaces increased, the bond strength values of the sample groups decreased (Soygun et al., 2013).

Various studies have been conducted on the adhesion of ozone gas to adhesive systems and dentin. In a study by Bitter et al., the effects of Er:YAG laser and ozone gas on the bond strength of different fiber post resin cements to root canals were examined. It was reported that the results varied depending on the materials (Bitter, Noetzel, Volk, & Neumann, 2008).

In a study by Kıvanç et al., the effect of ozone gas and neodymium-doped yttrium aluminum garnet (Nd:YAG) laser on the bond strength of fiber posts was investigated. The study concluded that neither ozone gas nor Nd:YAG laser had any effect on the bond strength of the fiber posts (Dalkilic et al., 2012).

Oral Surgery and Ozone

In oral surgery, ozone therapy can be used for hemostasis and local oxygen support, halting bacterial growth, temporomandibular joint dysfunctions, trismus, prevention of postoperative pain, cleansing the surface of avulsed teeth, treatment of soft tissue lesions (such as aphthous ulcers, herpes simplex, herpes zoster), and promoting healing in both bone and soft tissues. Additionally, ozone therapy can be beneficial in cases of alveolitis, peri-implantitis, refractory osteomyelitis treated with a combination of antibiotics, surgical intervention, and hyperbaric oxygen, as well as in the treatment of bisphosphonate-related osteonecrosis. It can also aid in tooth transplantation and decontamination of root surfaces of avulsed teeth before replantation, as well as in the disinfection of surgical sites before and after operations. Ozone gas application is recommended for these purposes (Saini, 2011).

In the treatment of oral lichen planus, a study comparing the clinical effectiveness of ozone, laser, and corticosteroid applications found that both ozone and corticosteroid treatments were effective (H O Kazancioglu, Kurklu, & Ezirganli, 2014; Hakki Oguz Kazancioglu & Erisen, 2015).

Several studies have investigated the use of ozone in third molar extraction surgery. These studies examined the contribution of ozone gas application to the effectiveness of treatment in cases of postoperative edema, pain, dry socket, and other unwanted complications, comparing it to other treatment methods such as laser, antibiotics, and placebo. While ozone application was found to positively contribute to the healing process, its effectiveness in treating complications was not definitively proven (Ahmedi, Ahmedi, Sejfija, Agani, & Hamiti, 2019; H O Kazancioglu et al., 2014; Prasad, Elavenil, Raja, Gayathri, & Lecturer, 2016).

In studies investigating the effect of ozone on dry socket, it was shown that ozone application had a positive effect on postoperative pain and infection in cases of pain and infection following third molar surgery. Researchers reported that ozone supported hemostasis, increased oxygen support, and inhibited bacterial proliferation (Ahmedi et al., 2019).

Studies have reported significant improvement in cases of osteonecrosis following ozone applications using different techniques (gas, ozonated water, or oil). In cases of bisphosphonate-related osteonecrosis, it has been reported that tooth extraction can be performed after ozone therapy (Akdeniz et al., 2017; Fliefel, Tro, & Ku, 2015; Tunç, Yaylı, & Bayar, 2018).

Al-Omiri et al. evaluated the efficacy of ozone therapy in the treatment of recurrent aphthous stomatitis and reported that ozone application reduced pain, decreased ulcer size, and accelerated wound healing (Al-omiri, Alhijawi, Alzarea, Hassan, & Lynch, 2016).

In the treatment of alveolitis, combining ozone therapy with alveogel treatment was found to result in faster healing without the need for additional systemic therapy. Some studies also recommend ozone therapy for the treatment of oral mucositis, although in an experimental study comparing the effects of laser and ozone, low-dose laser therapy was found to be more effective than ozone (Bayer, Kazancioglu, Acar, & Demirtas, 2017).

Clinical trials involving patients with internal irregularities of the temporomandibular joint reported significantly greater improvement in the ozone group, where ozonated water was applied during arthrocentesis (Doğan et al., 2014; Goldschlag, Kim, & Kristin, 2019; Özalp et al., 2019).

Points to Consider in Ozone Therapy:

1. Treatment of caries lesions that penetrate only the enamel surface can be more challenging and time-consuming.

2. It should be explained to the patient that traditional treatment techniques will be combined with the HealOzone system.

3. The goal of combined treatment is to strengthen and preserve dental tissue.

4. Soft debris must be removed to prevent mineral accumulation, which can inhibit remineralization.

5. If a mineral-containing gel is to be applied, it should be done 1-3 minutes after ozone application.

6. The use of Fuji VII is not mandatory, but the exposed surface should be self-cleansing. Air abrasion/prophyflex can create this environment.

Patients should be advised on oral hygiene education and reducing carbohydrate intake (Aylin Baysan, Whiley, & Lynch, 2000).

CONCLUSION

Ozone therapy holds significant potential in various areas of dentistry. It is particularly promising due to its less invasive nature compared to traditional treatment procedures. Ozone therapy has opened up new horizons in treatment methods for patients of all ages with dental conditions, and it can be applied to a wide range of intraoral hard and soft tissues. It possesses potent disinfectant properties, thereby reducing bacterial counts more specifically with minimal adverse effects. It reduces treatment duration and patient discomfort, thereby enhancing patient compliance and making it more acceptable for patients. It is especially suitable for patients who fear drilling and refuse traditional treatment methods. However, the effective use of ozone in routine dentistry has not yet been universally accepted due to inadequate knowledge, lack of education, and conflicting evidence in the literature. Therefore, for ozone therapy to be applied as a standard treatment method in dentistry, larger sample sizes, sufficient follow-up periods, standard measurements, and well-structured analyses with double/triple-blind randomized controlled trials are needed.

REFERENCES

Ahmedi, J., Ahmedi, E., Sejfija, O., Agani, Z., & Hamiti, V. (2019). Efficiency of gaseous ozone in reducing the development of dry socket following surgical third molar extraction. *European Journal of Dentistry*, *10*(3), 381–385. https://doi.org/10.4103/1305-7456.184168

Akdeniz, S., Beyler, E., Korkmaz, Y., Yurtcu, E., Ates, U., & Araz, K. (2017). The effects of ozone application on genotoxic damage and wound healing in bisphosphonate-applied human gingival fibroblast cells. *Clin Oral Invest*. https://doi.org/10.1007/s00784-017-2163-6

Al-omiri, M. K., Alhijawi, M., Alzarea, B. K., Hassan, S. A., & Lynch, E. (2016). Ozone treatment of recurrent aphthous stomatitis : a double blinded study. *Nature Publishing Group*, 1–7. https://doi.org/10.1038/srep27772

AL-Omiri, M. K., Hassan, R. S. A., AlZarea, B. K., & Lynch, E. (2016). Effects of combining ozone and hydrogren peroxide on tooth bleaching: A clinical study. *Journal of Dentistry*, *53*, 88–93. https://doi.org/10.1016/j.jdent.2016.08.002

Almaz, M. E., & Sönmez, I. Ş. (2015). Ozone therapy in the management and prevention of caries. *Journal of the Formosan Medical Association*, *114*(1), 3–11. https://doi.org/10.1016/j.jfma.2013.06.020

Arita, M., Nagayoshi, M., Fukuizumi, T., Okinaga, T., Masumi, S., Morikawa, M., & Kakinoki, Y. (2005). Microbicidal efficacy of ozonated water om candida albicans adhered to acrylic plates. *Oral Microbiology and Immunology*, *20*(6), 206–210.

Atabek, D. (2014). Diş çürüğünün tedavisinde ozon uygulamaları. *Acta Odontologica Turcica*, *31*(3), 149. https://doi.org/10.17214/aot.14100

Atabek, D., & Öztaş, N. (2012). Yüksek mineral içerikli ajanların ozon tedavisi ile kombine kullanımının fissür çürükleri üzerine etkisi. *Gazi Üniversitesi Diş Hekimliği Fakültesi Dergisi*, *29*(3), 165–171.

Azarpazhooh, A., & Limeback, H. (2008). The application of ozone in dentistry : a systematic review of literature. *Journal of Dentistry*, *36*, 104–116. https://doi.org/10.1016/j.jdent.2007.11.008

Babucçu, O. (2011). Ozon terapi : mit ve gerçek ozone therapy : myth and fact. *Türk Plastik Rekonstrüktif Ve Estetik Cerrahi Dergisi*, *3*, 105–112.

Bayer, S., Kazancioglu, H. O., Acar, A. H., & Demirtas, N. (2017). Comparison of laser and ozone treatments on oral mucositis in an experimental model. *Lasers in Medical Science*, *32*(3), 673–677. https://doi.org/10.1007/s10103-017-2166-1

Baysan, A., & Beighton, D. (2007). Assessment of the ozone-mediated killing of bacteria in infected dentine associated with non-cavitated occlusal carious lesions. *Caries Research*, *41*(5), 337–341. https://doi.org/10.1159/000104790

Baysan, Aylin, Whiley, R. A., & Lynch, E. (2000). Antimicrobial effect of a novel ozone generating device on microorganisms associated with primary root carious lesions in vitro. *Caries Research*, *34*(6), 498–501. https://doi.org/10.1159/000016630

Bhateja, S. (2012). The miraculous healing therapy e " ozone therapy " in dentistry. *Indian Journal of Dentistry*, *3*(3), 150–155. https://doi.org/10.1016/j.ijd.2012.04.004

Bitter, K., Noetzel, J., Volk, C., & Neumann, K. (2008). Bond strength of fiber posts after the application of erbium : yitrium aluminum garnet laser treatment and gaseous ozone to the root canal. *Journal of Endodontics*, *34*(3), 306–309. https://doi.org/10.1016/j.joen.2007.12.011

Bitter, K., Vlassakidis, A., Niepel, M., Hoedke, D., Schulze, J., Neumann, K., … Noetzel, J. (2017). Effects of diode laser , gaseous ozone and medical dressings on enterococcus faecalis biofilms in the root canal ex vivo. *BioMed Research International*, *6*, 1–9.

Bocci, V. A. (2006). Scientific and medical aspects of ozone therapy. State of the art. *Rivista Italiana Di Ossigeno-Ozonoterapia*, *5*(2), 93–104. https://doi.org/10.1016/j.arcmed.2005.08.006

Boztaş, G., & Ömürlü, H. (2015). Restoratif diş hekimliğinde ozon uygulamaları. *Atatürk Üniversitesi Diş Hekimliği Fakültesi Dergisi*, *9*(9). https://doi.org/10.17567/dfd.37551

Cardoso, M. G., & Oliveira, D. De. (2008). Effectiveness of ozonated water on candida albicans , enterococcus faecalis and endotoxins in root canals. *Oral Surgery Oral Medicine Oral Pathology Oral Radiology and Endodontology*, *105*(3), 85–91. https://doi.org/10.1016/j.tripleo.2007.10.006

Celiberti, P., Pazera, P., & Lussi, A. (2006). The impact of ozone treatment on enamel physical properties. *American Journal of Dentistry*, *19*(1), 67–72.

Çetinkaya, M., Aksoy, M., & Öz, F. T. (2021). Better with ozone or not ? An in-vivo study of ozone therapy as a pre-treatment before fissure sealant application . *Cumhuriyet Dental Journal*, *23*(4), 262–272. https://doi.org/10.7126/cumudj.772706

Çiçek, E., & Bodrumlu, E. (2013). Kök kanalında farklı irrigasyon solüsyonları varlığında yeni nesil apeks bulucu cihazların değerlendirilmesi. *Atatürk Üniv. Diş Hek. Fak. Derg.*, *1*(21), 37–42.

Dalkilic, E. E., Arisu, H. D., Kivanc, B. H., Uctasli, M. B., & Omurlu, H. (2012). Effect of different disinfectant methods on the initial microtensile bond strength of a self-etch adhesive to dentin. *Lasers in Medical Science*, *27*(4), 819–825. https://doi.org/10.1007/s10103-011-0987-x

Demir, H., Soygun, K., Dogan, A., Keskin, S., Dogan, O. M., & Bolayir, G. (2011). Effect of maleic anhydride pretreatment on tensile bond strength of a silicone soft liner to a denture base polymer. *J Adhes Dent*, *5*, 481. https://doi.org/10.3290/j.jad.a19817

Dıraçoğlu, D. (2016). Kas iskelet hastalıklarında ozon-oksijen tedavileri. *Turk J Phys*

Med Rehab, *62*(2), 183–191. https://doi.org/10.5152/tftrd.2015.87262

Doğan, M., Doğan, D. Ö., Düger, C., Kol, I. Ö., Akpinar, A., Mutaf, B., & Akar, T. (2014). Effects of high-frequency bio-oxidative ozone therapy in temporomandibular disorder-related pain. *Medical Principles and Practice*, *23*(6), 507–510. https://doi.org/10.1159/000365355

Dranguet, J., Fraga, A., Teresa, M., Mallok, A., Viebahn-hänsler, R., Fahmy, Z., … Fernández, L. (2013). Ozone oxidative postconditioning ameliorates joint damage and decreases pro-in fl ammatory cytokine levels and oxidative stress in PG / PS-induced arthritis in rats. *European Journal of Pharmacology*, *714*(1–3), 318–324. https://doi.org/10.1016/j.ejphar.2013.07.034

Eltaş, A., & Yücel, S. (2013). Kronik periodontitisin tedavisinde gaz ozon kullanımının halitosise etkisi. *İnönü Üniversitesi Sağlık Bilimleri Dergisi*, *2*(1), 1–4.

Elvis, A. M., & Ekta, J. S. (2011). Ozone therapy: a clinical review review article. *Journal of Natural Science*, *2*(1), 66–70. https://doi.org/10.4103/0976-9668.82319

Fliefel, R., Tro, M., & Ku, J. (2015). Treatment strategies and outcomes of bisphosphonate-related osteonecrosis of the jaw with characterization of patients : a systematic review. *International Association of Oral and Maxillofacial Surgeons*, *44*(5), 568–585. https://doi.org/10.1016/j.ijom.2015.01.026

Goldschlag, N., Kim, J. D., & Kristin, M. (2019). Use of ozone in temporomandibular joint arthrocentesis. *Journal of Chemical Information and Modeling*, *53*(9), 1689–1699.

Goztas, Z., Onat, H., Tosun, G., Sener, Y., & Hadimli, H. H. (2014). Antimicrobial effect of ozonated water , sodium hypochlorite and chlorhexidine gluconate in primary molar root canals. *European Journal of Dentistry*, *8*(4), 469. https://doi.org/10.4103/1305-7456.143627

Gracer, R. I., & Bocci, V. (2005). Can the combination of localized "' proliferative therapy "' with "' minor ozonated autohemotherapy "' restore the natural healing process ? *Elsevier*, 752–759. https://doi.org/10.1016/j.mehy.2005.04.021

Gupta, G., & Mansi, B. (2012). Ozone therapy in periodontics. *Journal of Medicine and Life*, *5*(1), 59–67.

Habashneh, R. Al, Alsalman, W., & Khader, Y. (2015). Ozone as an adjunct to conventional nonsurgical therapy in chronic periodontitis : a randomized controlled clinical trial. *Journal of Periodontal Research*, *50*(1), 37–43. https://doi.org/10.1111/jre.12177

Hauser-gerspach, I., Vadaszan, J., Deronjic, I., & Gass, C. (2012). Influence of gaseous ozone in peri-implantitis : bactericidal efficacy and cellular response . An in vitro study using titanium and zirconia. *Clin Oral Invest*, *16*, 1049–1059. https://doi.org/10.1007/s00784-011-0603-2

Hubbezoglu, I., Zan, R., Tunc, T., & Sumer, Z. (2014). Antibacterial Efficacy of Aqueous Ozone in Root Canals Infected by Enterococcus faecalis. *Jundıshapur Journal of Mıicrobiology*, *7*(7), 10–14. https://doi.org/10.5812/jjm.11411

Inal, M., Dokumacıoglu, A., Özcelik, E., & Ucar, O. (2011). The effects of ozone therapy and coenzyme Q 10 combination on oxidative stress markers in healthy subjects. *Irish Journal of Medical Science*, *180*, 703–707. https://doi.org/10.1007/s11845-011-0675-7

Kazancioglu, H O, Kurklu, E., & Ezirganli, S. (2014). Effects of ozone therapy on pain, swelling, and trismus following third molar surgery. *J. Oral Maxillofac. Surg*, *43*, 644–648. https://doi.org/10.1016/j.ijom.2013.11.006

Kazancioglu, Hakki Oguz, & Erisen, M. (2015). Comparison of low level laser therapy versus ozone therapy in the treatment of oral lichen planus. *Ann Dermatol*, *27*(5), 485–491.

Knight, G. M., McIntyre, J. M., Craig, G. G., Mulyani, & Zilm, P. S. (2008). The inability of streptococcus mutans and lactobacillus acidophilus to form a biofilm in vitro on dentine pretreated with ozone. *Australian Dental Journal*, *53*(4), 349–353. https://doi.org/10.1111/j.1834-7819.2008.00077.x

Korkut, Y., Ayada, C., & Toru, Ü. (2015). Ozon tedavisi ve servikal - lomber disk hernileri üzerine etkisi. *Ankara Med*, *15*(3), 161–168. https://doi.org/10.17098/amj.88945

Küçükkolbaşı, H., & Korkmaz, H. (2013). Diş hekimliğinde ozon uygulamaları. *Atatürk Üniv. Diş Hek. Fak. Derg.*, 125–134.

Küden, C., & Karakaş, S. N. (2021). Güncel dezenfektan yöntemlerinin kök kanal dentin mikrosertliği üzerine etkisi. *Balıkesir Sağlık Bilimleri Dergisi*, *10*(3), 405–409.

Nagayoshi, M., Fukuizumi, T., Kitamura, C., Yano, J., Terashita, M., & Nishihara, T. (2004). Efficacy of ozone on survival and permeability of oral microorganisms. *Oral Microbiology and Immunology*, *19*(4), 240–246. https://doi.org/10.1111/j.1399-302X.2004.00146.x

Naik, S. V, Rajeshwari, K., Kohli, S., Zohabhasan, S., & Bhatia, S. (2016). Ozone- a biological therapy in dentistry- reality or myth ? *The Open Dentistry Journal*, *11*(10), 196–206. https://doi.org/10.2174/1874210601610010196

Nogales CG, Ferrari PH, Kantorovich EO, L. J. (2008). Ozone therapy in medicine and dentistry. *The Journal of Contemporary Dental Practice*, *9*(4). Retrieved from https://www.thejcdp.com/doi/JCDP/pdf/10.5005/jcdp-9-4-75

Özalp, Ö., Yıldırımyan, N., Sindel, A., Altay, A., Kişnişci, R. Ş., Cavalcanti, A. L., … Padilha, N. (2019). Evaluation of the short term efficacy of transdermal ozone therapy in turkish patients with internal derangement of the temporomandibular joint. *Pesquisa Brasileira Em Odontopediatria e Clínica Integrada*, *19*, 4442. https://doi.org/10.4034/PBOCI.2019.191.44

Patel, P. V., Kumar, V., Kumar, S., Gd, V., & Patel, A. (2011). Therapeutic effect of topical ozonated oil on the epithelial healing of palatal wound sites : a planimetrical and cytological study. *J Investig Clin Dent*, *2*(4), 248–258. https://doi.org/10.1111/j.2041-1626.2011.00072.x

Patel, V. P., Patel, A., Kumar, S., & C., H. J. (2013). Evaluation of ozonated olive oil with or without adjunctive application of calcium sodium phosphosilicate on post-surgical root dentin hypersensitivity: a randomized, double-blinded, controlled, clinical trial. *Minerva Stomatologica*, *62*(5), 147–161.

Pinna, A., Molicotti, P., Sechi, L. A., Lezcano, I., Nunez, N., Espim, M., & Dupre, I. (2001). Antibacterial activity of ozonized sun ower oil (Oleozon). *Journal of Applied Microbiology*, *90*, 279–284.

Pires, P. T., Ferreira, J. C., Oliveira, S., Silva, M. J., & Melo, P. R. (2013). Effect of ozone gas on the shear bond strength to enamel. *Journal of Applied Oral Science*, *21*(2), 177–182. https://doi.org/10.1590/1678-7757201302362

Prasad, S. V., Elavenil, P., Raja, V. B. K., Gayathri, G., & Lecturer, S. (2016). Does topical ozone therapy improve patient comfort after surgical removal of impacted mandibular third molar? A randomized controlled trial. *Journal of Oral and Maxillofacial Surgery*, *75*(1), 51. https://doi.org/10.1016/j.joms.2016.09.014

Reddy, K. S., Prasad, S. D., Sirisha, P. D., & Prashanth, V. (2015). Evaluation of antimicrobial efficacy of ozonated sesame oil, calcium hydroxide and their combination as intracanal medicament against candida albicans: an in-vitro study. *Adv Hum Biol*, *5*(2), 78–87.

Sadatullah, S., Mohamed, N. H., & Razak, F. A. (2012). The antimicrobial effect of 0 . 1 ppm ozonated water on 24-hour plaque microorganisms in situ. *Braz Oral Res*, *26*(2), 126–131.

Saini, R. (2011). Ozone therapy in dentistry: a strategic review. *Journal of Natural Science, Biology and Medicine*, *2*(2), 151–153. https://doi.org/10.4103/0976-9668.92318

Sarı, M. (2022). Ozone therapy in dentistry. *Current Research in Dental Sciences*, *32*(1), 100–107. https://doi.org/10.17567/ataunidfd.888905

Sousa, S. I. V., Alvim-Ferraz, M. C. M., Martins, F. G., & Pereira, M. C. (2009). Ozone exposure and its influence on the worsening of childhood asthma. *Allergy: European Journal of Allergy and Clinical Immunology*, *64*(7), 1046–1055. https://doi.org/10.1111/j.1398-9995.2009.01946.x

Soygun, K., Bolayır, G., & Kapdan, A. (2013). Effect of ozone gaseous to tensile bond strength between soft liner and PMMA Yumuşak astar ve PMMA arasındaki çekme bağlantı dayanımına ozon gaz etkisi. *Cumhuriyet Dental Journal*, *17*(3), 215–222. https://doi.org/10.7126/cdj.58140.1008002381

Sürmelioğlu, D., Bacaksız, B., & Özsevik, S. (2016). Bleaching with three different treatment methods: report of 3 cases. *Journal of International Dental Sciences*, *1*(1). https://doi.org/10.21306/jids.2015.1.10

Suzuki, T., Oizumi, M., & Medical, T. (1999). Influence of ozone on oxidation of dental alloys. *Int J Prosthodont*, *12*(2), 179–184.

Tahmassebi, J. F., Chrysafi, N., & Duggal, M. S. (2014). The effect of ozone on progression or regression of artificial caries-like enamel lesions in vitro. *Journal* *of Dentistry*, *42*(2), 167–174. https://doi.org/10.1016/j.jdent.2013.11.011

Tiwari, S., Avinash, A., Katiyar, S., Aarthi Iyer, A., & Jain, S. (2017). Dental applications of ozone therapy: a review of literature. *Saudi Journal for Dental Research*, *8*(1–2), 105–111. https://doi.org/10.1016/j.sjdr.2016.06.005

Toprak, Ş. (2021). Ozone generator and ozone generation. *Journal of Amasya University the Institute of Sciences and Technology*, *2*(2), 16–25. https://doi.org/10.54559/jauist.981674

Torul, D., Ayrancı, F., Ömezli, M. M., & Yılmaz, M. F. (2021). Ozonun temporomandibular eklem bozukluklarının tedavisindeki yeri. *Odü Tıp Dergisi*, *8*(4), 22–30.

Tunç, S. K., Yaylı, N. Z. A., & Bayar, T. (2018). Dentoalveolar cerrahide ozon tedavisi. *Uluslararası Diş Hekimliği Bilimleri Dergisi*, *2*, 57–63. https://doi.org/10.21306/jids.2018.120

Tuncay, Ö., Er, Ö., Demirbuga, S., Zorba, Y. O., & Topcuoğlu, H. S. (2016). Effect of gaseous ozone and light activated disinfection on the surface hardness of resin based root canal sealers. *Scanning*, *38*(2), 141–147. https://doi.org/10.1002/sca.21222

Ünal, M., & Öztaş, N. (2015). Remineralization capacity of three fissure sealants with and without gaseous ozone on noncavitated incipient pit and fissure caries. *J Clin Pediatr Dent*, *39*(4), 364.

Virtej, A., MacKenzie, C. R., Raab, W. H. M., Pfeffer, K., & Barthel, C. R. (2007). Determination of the performance of various root canal disinfection methods after in situ carriage. *Journal of Endodontics*, *33*(8), 926–929. https://doi.org/10.1016/j.joen.2006.11.025

Yamaner, F. E., Celakil, T., & Gökcen Roehlig, B. (2020). Comparison of the efficiency of two alternative therapies for the management of temporomandibular disorders. *Cranio - Journal of Craniomandibular Practice*, *0*(0), 1–10. https://doi.org/10.1080/08869634.2020.1727667

CHAPTER 5

TRANSVERSE MAXILLARY DEFICIENCY: CURRENT MANAGEMENT MODALITIES

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1. Introduction

The most prevalent alteration of the maxilla is transverse maxilla deficiency (TMD). A stable and functioning occlusion depends critically on having an appropriate transverse maxillary dimension. Thus, early identification of TMD affects the efficacy of the treatment. Since the middle of the 19th century, several approaches to treating TMD have been documented and are still evolving today. However, there is currently a lack of consensus regarding the optimum management of TMD (Bin Dakhil & Bin Salamah, 2021; Mubeen, Shah, Cronin, & Sharma, 2023).

Planning, diagnosis, and treatment have all been impacted by research and technological advancements. The most recent trend is toward treatment approaches that allow for cheaper costs while maintaining the best standards of skeletal, functional, and soft tissue esthetic outcomes, as well as enhanced efficiency and shorter operating times. With TMD being a common clinical problem for clinicians, this study attempts to give a thorough evaluation regarding the diagnosis and treatment of TMD and provide an update on current management strategies.

2. Transverse Maxillary Deficiency

Deformities in the dentofacial region are abnormalities that can manifest in the three planes of space and can be unilateral or bilateral (Pereira et al., 2022). With a prevalence of 8–30%, TMD is a frequent discrepancy encountered in adults and adolescents (Carvalho et al., 2019; Chhatwani et al., 2021; Pereira et al., 2022). Uni-bilateral crossbite, crowding, increased buccal corridor presentation, narrow maxillary arch form, high and narrow palatal arch, and lip incompetence are clinical indicators of TMD that may cause cosmetic and functional problems (Martin et al., 2023; Pereira et al., 2022; Zambon et al., 2012). TMD is mostly characterized by posterior crossbite, which is one of the most prevalent types of malocclusions, with a prevalence ranging from 8 to 22 % (Feng et al., 2023; Zupan, Ihan Hren, & Verdenik, 2022). If left untreated, occurrences of posterior crossbite can lead to detrimental changes in the temporomandibular joint, such as facial asymmetry, midline deviation, and changed condylar position in the mandibular fossa (Carvalho et al., 2019).

Deficits in transverse growth can also impact craniofacial development since it occurs before sagittal and vertical development (Feng et al., 2023). Therefore, craniofacial changes, such as a narrowed alar base and nasal cavity, increased airflow resistance, and a higher frequency of nasal obstruction, may also be present in addition to dentoalveolar disturbances. These changes may increase the frequency of breathing issues, such as mouth breathing (Feng et al., 2023; Liu, Wei, Dai, & Wang, 2020; Zambon et al., 2012). To improve esthetics and function as well as the relation between the jaws, TMD must be corrected in a timely manner (Feng et al., 2023).

Etiology

Multiple factors may contribute to the complex etiology of TMD. Congenital, developmental, traumatic, or iatrogenic factors can all be considered potential etiologic parameters for TMD. As a result of syndromes, TMD can also arise (Laino et al., 2016; Zambon et al., 2012). Although, the majority of individuals with TMD have non-syndromal dysphagia, individuals with cleft lip and palate or craniofacial syndromes may also experience this condition (Landes et al., 2012).

Diagnosis

For long-term stability, a precise diagnosis and course of treatment for TMD are essential (Pereira et al., 2022). Usually, the clinical examination and the patient's history are used to reach an initial diagnosis. Functional analysis, radiographic evaluation (i.e., computed tomography, cephalometric, and panoramic radiographs), photographic, and model evaluations are other steps that follow in making the definitive diagnosis (Laino et al., 2016). Although a typical posteroanterior cephalogram can be utilized, a clinical examination and model evaluation are considered the most effective diagnosis methods for this abnormality (Kurt et al., 2017; Pereira et al., 2022). The degree of palatal expansion and the course of expansion can both be explored using contour tracings of the study models, which helps get beyond the constraints of evaluating the alterations in the palatal vault area (Kurt et al., 2017).

2.1. Crossbite Definition and Classification

Posterior crossbite (PCB) is typified by a maxillary arch that is more constricted than the mandibular arch in one or both sides, as well as maxillary posterior teeth that are lingually positioned in respect to mandibular posterior teeth (Loriato & Ferreira, 2020). PCB can be further classified as unilateral and bilateral, or as skeletal, dental, and functional (Karabiber & Yilmaz, 2023b). Maxillary atresia is the characteristic of skeletal posterior crossbite in which the maxillary narrower than the mandible transversally (Loriato & Ferreira, 2020). True unilateral PCs (TUPC) and functional PCs (FPC) are the two categories into which unilateral PCs are separated. FPC makes up between 67% and 79% of unilateral PCs. These two discrepancies have different diagnosis and treatment approaches. When the mouth is opened and closed, there is a mandibular shift and bilateral maxillary constriction in FPC. Midlines do not coincide during intercuspation, but when the mouth is open, upper and lower midlines coincide. Moreover, TUPC exhibits a more constricted maxillary arch on single side and maintains the same midline coincidence when the mouth is opened and closed. When treating TUPC, maxillary expansion unilaterally is necessary to prevent non-occlusion on the normal side, whereas FPC therapy involves bilateral maxillary expansion (Karabiber & Yilmaz, 2023b).

2.2. Transversal Maxillary Deficiency Treatment

There are various methods that can be used to treat TMD, such as rapid maxillary expansion (RME), slow maxillary expansion (SME), miniscrew assisted palatal expansion (MARPE), and surgically assisted maxillary expansion (SARME) (Berkun, Findik, Akpinar, Ay, & Baykul, 2022; Loriato & Ferreira, 2020). Maximal dental arch correction and minimal dental movement are the main goals of maxillary expansion (Feng et al., 2023). Treatment determination is primarily based on the skeletal maturation stage and the severity of maxillary transverse insufficiency (Oliveira, Pereira-Filho, Gabrielli, Goncales, & Santos-Pinto, 2016).

For children and young patients, orthopedic maxillary expansion approaches are recommended for the rehabilitation of the TMD (Oliveira et al., 2016). When using an orthopedic approach, maxillary expansion can be rapid (RME) or slow (SME) based on the force applied, the appliance, the way the screw on the expander is activated, and how long the patient receives treatment (Rutili et al., 2021). RME, which is usually carried out in early adolescence between 10 and 13 years, is the most popular orthodontic therapeutic treatment strategy for maxillary expansion. Both RME and SME methods can have specific consequences; however, SME causes less molar tipping and RME is comparatively more effective in widening the maxilla's posterior (Feng et al., 2023). Use of either fixed or removable appliances can accomplish the widening of the maxilla for both RME and SME. In order to widen the upper arch during therapy, these appliances must be activated periodically (Rutili et al., 2022). However, SARME is preferred for adult patients since it can weaken sutures during expansion (Oliveira et al., 2016).

2.2.1. Rapid Maxillary Expansion

RME is currently one of the most frequently used and recognized therapeutic modalities for treating individuals with TMD during the peak period of growth and development (Feng et al., 2023; Sant'Ana, Pinzan-Vercelino, Gurgel, & Carvalho, 2016). After being presented by Angell in 1860, RME became well-known in the late 1900s (Huang, Han, & Yang, 2022). RME is frequently used to treat skeletal Class II and III patients, nasal airway resistance, transverse maxillary skeletal or dental deficit, moderate crowding cases to lengthen the arch and sleep-disordered breathing (Kurt et al., 2017; Marino Merlo et al., 2024). Appliances attached to teeth or tissues (e.g., Hyrax or Haas) in growing patients are used to achieve RME, which is attached to systems of heavy and intermittent stresses applied in a brief amount of time (Rutili et al., 2021; Rutili et al., 2022). Tooth-borne expanders are preferred very commonly in RME approach (Huang et al., 2022). However, many side effects, including limited skeletal movement, dental tilting, root resorption, negative periodontal consequences (such dehiscence), and lack of long-term stability, may be associated with traditional tooth-borne RME. However, it has been shown that in general RME appliances are increases the openness of bone sutures and lowers nasal airway resistance (Feng et al., 2023). Usually, the RME activation strategy entails a quarter turn once or twice a day, resulting in a 0.25–0.5 mm daily expansion (Rutili et al., 2021).

RME alters the craniofacial structure in addition to the dentofacial structure. Because the maxilla is related to numerous other bones, the consequences of RME extend beyond the upper jaw. RME lowers the palatal vault, straightens the nasal septum, and divides the nasal cavity's external walls laterally. This remodeling enhances breathing, expands internasal capacity, and reduces nasal resistance (Babacan, Sokucu, Doruk, & Ay, 2006).

In a patient with a mature skeleton, RME can also have negative consequences such as posterior teeth that are tipped laterally, extrusion, compression of the periodontal membrane, recession of the periodontal tissue, resorption of the buccal root, alveolar bone bending, palatal tissue necrosis, discomfort, and instability of the expansion (Aktop, Gönül, Garip, & Göker, 2015; Huang et al., 2022; Kurt et al., 2017).

2.2.2. Slow Maxillary Expansion

The main disadvantages of RME are the pain and discomfort experienced by the young patient and the requirement for parental and pediatric patient compliance in order to activate the appliance. Regarding the symptoms that patients went through, RME is regarded as one of the most excruciating early orthodontic operations. SME, often referred to as dentoalveolar expansion, is a process that involves transverse palate widening using orthodontic appliances (Khan, Sharma, & Jindal, 2023). Compared to RME, SME uses continuous low-force systems that applied over a longer time. SME can be produced using more modern devices like the Leaf Expander (E.L.A.) or even RME devices (Haas, Hyrax) that use a different activation protocol than that used for RME (Rutili et al., 2021; Rutili et al., 2022).

One disadvantage of SME is that it requires longer treatment times than quick maxillary growth. SME is advised for individuals who have a crossbite in order to create gaps and reduce mild crowding. Patients with cleft lip and palate and mild maxillary constriction should consider gradual palatal expansion, which involves gentle, ongoing pressures on the patient (Khan et al., 2023).

2.2.3. Surgically Assisted Rapid Maxillary Expansion

Increased skeletal resistance in non-growing patients with completed skeletal maturity makes RME inappropriate, and surgical expansion is the best course of action for correction (Abate, Lanteri, Marcolongo, Solimei, & Maspero, 2023; Berkun et al., 2022; Gogna, Johal, & Sharma, 2020). For adults and adolescents with nongrowing skeletons who are under orthodontic therapy, SARME has been shown to be a dependable technique. In a transverse plane, it combines controlled soft tissue expansion with distraction osteogenesis of the maxilla. SARME allows the dental arch to expand transversely, gives the tongue enough area, and eventually harmonizes the tooth arches (Pereira et al., 2022). It entails a Le Fort I subtotal osteotomy, which works with an expanding orthodontic appliance supported by the bone or teeth, to lessen maxillary pillar resistance during transverse expansion (Carvalho et al., 2019). In order to synchronize the upper and lower arches and rectify malocclusion in adult patients with severe TMD, SARME is thought to be an effective therapy (Liu et al., 2020). After the course of therapy, both a functional and an efficient occlusal relationship with balanced muscle activity are anticipated (Abate et al., 2023).

For the treatment of severe TMD in skeletally mature patients, SARME, which combines orthodontics and surgical treatments, is becoming a commonly utilized therapy. Three different types of expanders can be used for SARME surgeries. They are combination appliances, appliances borne on the bone, and appliances borne in the teeth (Zupan et al., 2022). In addition to causing palatal enlargement, SARME also modifies the structure of the craniofacial region, increasing nasal cavity breadth and nasal volume (Seidita et al., 2022). Additional cranial structural abnormalities brought on by SARME include palatal vault, nasal cavity width, and nasal volume augmentation. The separation of the nasal lateral walls is the basis for SARME's effect on the nasal cavity. Breathing is made easier by the increase in nasal volume and cross-sectional area caused by the separation of the nasal cavity's lateral walls (Gurler, Akar, Delilbasi, & Kacar, 2018). It has been shown that an increase in the maxilla's transverse dimensions enlarges the nasal cavity and lessens the degree of nasal blockage (Gurler et al., 2018; Zambon et al., 2012). Changes in the face after SARME reflect the underlying movements of the dento-skeletal system. The two most reported findings are a wider nose and a higher lateral projection of the cheek region. Following SARME, there were also reports of a little retropositioning of the upper lip and an anterior-inferior displacement of the entire naso-maxillary complex (Zupan et al., 2022). The primary impacts of SARME are transversal; however, research has also revealed skeletal alterations due to expansion in the sagittal and vertical planes. There is disagreement over the degree and durability of these changes, however one of the main impacts of SARME on mandibular placement has been described as the clockwise rotation (Oliveira et al., 2016). The main aims of the SARME shown in figure 1 (Aktop et al., 2015).

SARME, however, is an expensive, traumatic procedure that frequently results in complications. Moreover, due to the 2-phase surgery necessity, SARME is not a good solution for patients with maxillary constriction and substantial anteroposterior discrepancies (Huang et al., 2022).

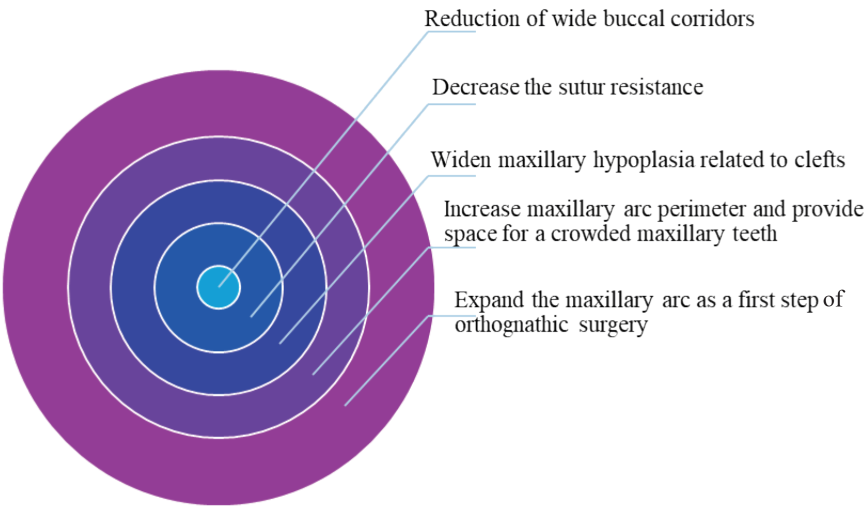

Figure 1: *The main aims of SARME*

Indications

SARME performed with the indications as follows;

- Patient age
- Maxillomandibular transverse discrepancy more than 5 mm
- Severe discrepancy with maxillary hypoplasia linked to hypermandible
- Unsuccessful orthodontic therapy
- Thin periodontal biotype
- Transverse maxillary hypoplasia, either unilateral or bilateral
- Unilateral or bilateral cross-bites
- A small dentoalveolar base
- Dental crowding
- Ossified palatal suture
- Larger buccal corridors when smiling

- An unfavorable buccal tooth inclination

- Individuals experiencing severe discomfort, edema, and palate lesions during orthopedic expansion; these patients may also have craniosynostosis syndrome.

- Getting ready for orthognathic surgery in cases of substantial (more than 7 mm) dentofacial abnormalities in order to promote or increase stability or accomplish dental decompensation

- Severe gingival recession or loss of periodontal bone (Chhatwani et al., 2021; Gogna et al., 2020; Kurt et al., 2017; Laino et al., 2016; Landes et al., 2012; Loriato & Ferreira, 2020; Magnusson, Bjerklin, Nilsson, & Marcusson, 2009; Martin et al., 2023).

Surgical Phase and Current Approaches

Since Angell first proposed the idea of treating TMD in 1860, it has undergone a number of modifications. Other maxillary articulations are shown to be the increased facial skeletal resistance sites to expansion, despite the fact that the midpalatal suture was previously believed to be the location of resistance to expansion (Aktop et al., 2015). The pyriform aperture (anterior), the pterygoid junction (posterior), the zygomatic buttress (lateral), and the midpalatal synostosis suture (median) are currently proposed as the areas of resistance in the midface (Aktop et al., 2015). Pterygomaxillary, zygomaticomaxillary, and frontomaxillary sutures are thought to provide the majority of the resistance to distraction movement that is observed (Gurler et al., 2018; Laino et al., 2016). The discovery of these resistance sites in the craniofacial skeleton prompted the creation of several adjustments to maxillary osteotomies, which enlarged the maxilla when combined with orthodontic equipment (Bortolotti et al., 2020; Feng et al., 2023; Gogna et al., 2020; Sant'Ana et al., 2016).

SARME surgery is performed similarly to Le-Fort 1 osteotomy surgery, with the exception of a down fracture. To make the resistance areas visible, a mucoperiosteal flap is elevated. Depending on the desired method, maxillary corticotomies were performed using a reciprocating micro-saw or piezo surgical device in all or some of the resistance areas of the zygomatic buttress, the midpalatal suture, the pterygoid junction, and the pyriform aperture (Figure 2). Separating the nasal septum can help stop deviation during the activation phase. At the conclusion of the procedure, the orthodontic appliance is turned on to confirm that the osteotomy was successful and that the bone segments were separated symmetrically. After that, the incision was mostly closed, and the appliance was turned off. The appliance began to activate after the latency time. Activation continued until the desired expansion was accomplished (Aktop et al., 2015; Gurler et al., 2018; Jensen & Rodrigo-Domingo, 2017; Martin et al., 2023; Zambon et al., 2012).

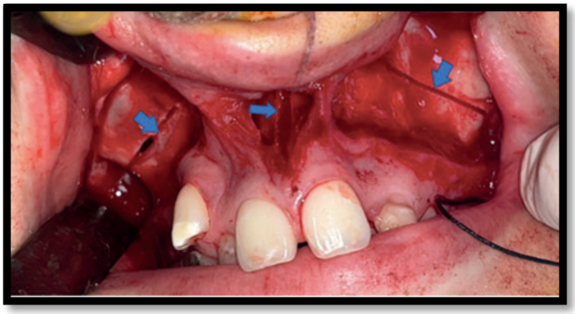

Figure 2. *Intraoperative view of the osteotomy lines*

When posterior crossbite is observed unilaterally, the expansion protocol might need to be adjusted. Numerous asymmetric expansion tools and strategies have been tested for unilateral expansion. In skeletally mature and nongrowing adults, however, surgical aid should be added to lower bone resistance during RME. Following sutural closure, anterior, lateral, and posterior osteotomies exclusively on the crossbite side as well as a median osteotomy of the midpalatal suture are the preferred osteotomies for TUPC (Karabiber & Yilmaz, 2023a).

After surgery, it's critical to plan the distraction's rhythm. If diversion is done too quickly, it may result in nonunion or malunion; if it is done too slowly, premature consolidation may happen (Aktop et al., 2015). Despite the literature's widespread recommendation of SARME, there is ongoing discussion on the optimal surgical strategy, including the number/location of osteotomies, the kind of appliance, when to start activation, and if overtreatment is necessary (Carvalho et al., 2019; Pereira et al., 2022). Numerous protocols linked to SARME have been suggested (Table 1).

Table 1: *Clinical Studies about SARME*

Author/Date	Design	No. of patients/Age/gender	Buttress Released	Appliance Used	Complication
(Laudemann et al., 2009)	R, P	50 (Gender: NA) Mean age: 25 yr	ZB, +PMD (n =21), ZB, -PMD (n =29)	Bone-borne/ Tooth-borne appliances	-
(Magnusson et al., 2009)	P	31 (17M, 14F) Mean age: 15.7 – 48.9 yr	ZB, +PMD, the piriform aperture pillars, -palatal osteotomy, midline osteotomy	Hyrax	-
(Seeberger, Kater, Davids, & Thiele, 2010)	R	13 (8F, 5M) Mean age: 31.23 ± 6.11 yr	ZB, -PMD, midline osteotomy	Hyrax	-
(Nada et al., 2012)	P	45 (17M, 28F) TPD group (Mean age: 29.4 ± 10 yr), Hyrax group (Mean age: 24.5 ± 9 yr)	ZB, +PMD, midline osteotomy	Hyrax, n =28 TPD, n=17	-
(Landes et al., 2012)	R, P	81 (39M, 42F) Mean age 24.3 ± 8.7 yr	ZB, -PMD, 3SO (n=24), 2SO (n=57)	Hyrax TPD	-
(Reinbacher et al., 2013)	R	25 (12 M, 13 F) Mean age: 30 yr	ZB, -PMD midline osteotomy nonreleasing of the nasal septum	Haas	-
(Sygouros, Motro, Ugurlu, & Acar, 2014)	R	20 (4M, 16 F) 10 Mean age: 18.4 yr 10 Mean age: 19.2 yr	ZB, +PMD, midline osteotomy ZB, -PMD midline osteotomy	Hyrax	Buccal alveolar bending and Buccal tipping
(Zandi, Miresmaeili, Heidari, & Lamei, 2016)	RCT	15 (6M, 9F) Mean age: 20.69 yr 15 (7M, 8F) Mean age: 21.26 yr	ZB, +PMD, nonreleasing of the nasal septum, midline osteotomy ZB, -PMD, nonreleasing of the nasal septum, midline osteotomy	Hyrax	Tooth extrusion (n=1)
(Oliveira et al., 2016)	R	30 (11M, 19F) 16 Mean age: 30.4 yr 14 Mean age: 24.2 yr	ZB, +PMD, midpalatal suture osteotomy, and lateral osteotomy performed in a horizontal straight fashion. ZB, +PMD, midpalatal suture osteotomy, and lateral osteotomy performed in parallel to the occlusal plane + step at the ZB	Hyrax(n=16) Hyrax(n=8) Haas(n=6)	-
(Sant'Ana et al., 2016)	P	24 (6M, 18F) Mean age: 24.29-3.48 yr	ZB, -PMD, midpalatal split, (n =14) ZB, -PMD, without midpalatal split (n = 10)	Hyrax	-
(Jensen & Rodrigo-Domingo, 2017)	R	10 (4 M, 6 F) Mean age: 18 yr, 10 (5 M, 5 F) Mean age: 23 yr,	ZB, +PMD, releasing of the nasal septum ZB, +PMD, nonreleasing of the nasal septum	Bone-borne/ Tooth-borne appliances	-
(Xi et al., 2017)	R	78 (22M, 56F) Mean age: 27.2 ± 10.4 yr	ZB, +PMD, midline osteotomy	Hyrax TPD	-
(Pereira et al., 2022)	P	19 (12F, 7M) Mean age: 25.7 yr	ZB, +PMD, midline osteotomy, 3SO (n=9), 2SO (n=10)	Hyrax	Necrosis of a central incisor (2SO)

M: Male, **F**: Female, **P**: Prospective, **R**: Retrospective, **RCT**: Randomized Controlled Trial, **3SO**: Three-segment (paramedian) osteotomy, **2SO**: Two-segment (median) osteotomy, **ZB**: Zygomatic Buttress, **TPD**: Trans palatal Distractor, **PMD**: Pterygomaxillary disjunction

Complications of SARME

In actuality, whilst SARME is a safe and successful method, complications can unavoidably arise both during and after surgery (Aktop et al., 2015; Carvalho et al., 2019; Kurt et al., 2017; Oliveira et al., 2016), (Figure 3).

Complications	Asymmetric or incorrect expansion
	Tooth loss
	Tissue necrosis
	Severe tooth resorption
	Severe bleeding
	Palatal fistula
	Insufficient expansion and relapse
	Pain
	Tooth discolouration
	Extrusion or mobility
	Blunting of the dental apices
	Mild periodontal bone loss or gingival recession
	Epistaxis or intraoral hemorrhage
	Wound dehiscence
	Local infection or inflammation
	Transient headache or lacrimation or tinnitus, nausea or vomiting, or numbness
	Device-related complications
	Swelling, edema
	Ulceration, and bite opening
	Maxillary nerve injury
	Vitality loss of teeth
	Orbital compartment syndrome
	Alar base flaring
	Sinus infection
	Rupture of inferior nasal mucosa or any damage of venous plexus
	Septum deviation

Figure 3: *Complications of SARME*

2.2.4. Miniscrew-assisted Rapid Palatal Expansion

Clinicians started searching for less intrusive treatments to streamline the therapeutic process and lower the risk of side effects (Zeng et al., 2023). In order to achieve maxillary expansion without requiring surgery, MARPE was developed in conjunction with the usage of mini-implant (Huang et al., 2022). The MARPE method has gained popularity recently. It involves implanting miniscrews in the palate together with rigid parts and a traditional RME device (Zeng et al., 2023). The miniscrews that are inserted into the para-midpalatal region are connected to the MARPE appliance (Huang et al., 2022). Utilizing two or four mini-implants, MARPE exerts the expansion force (Feng et al., 2023). As a result, the appliance can maximize the skeletal effect by directly applying the expansion force to the maxilla and midpalatal suture. This allows for more orthodontic adjustments and lessens the adverse effects on the teeth and alveolar bone (Feng et al., 2023; Huang et al., 2022). Although there are no age restrictions stated in the literature, it is often recommended for young adults in their 20s to 30s (Loriato & Ferreira, 2020).

When compared to RME, MARPE could lessen undesirable side effects while producing stronger skeletal effects (Zeng et al., 2023). In contrast to SARME, MARPE is less intrusive, more affordable, does not result in surgical complications, and may not cause unfavorable outcomes during maxillary expansion, such as incisor discoloration, asymmetrical expansion, and periodontal problems (Feng et al., 2023; Loriato & Ferreira, 2020).

3. Conclusion

Clinicians are still interested in and debating appliance designs, methods, and techniques when it comes to treating TMD. A large portion of the debate centers on whether or not surgical measures of expansion are necessary, as well as whether or not nonsurgical expansion treatments are appropriate. In addition to the maxilla, other craniofacial components are also affected by TMD management, which impacts the appearance and functionality of the face. Orthodontic treatment is currently recommended for patients who are growing, while surgery is meant for patients who have reached verified skeletal maturity. Nevertheless, there is ongoing discussion about how best to manage TMDs, and there doesn't appear to be any consensus regarding the best course of treatment approach or equipment for management of TMD. As being a popular research area in the scientific community further studies needed to clarify the optimum management procedure for the TMD with case specific manner.

REFERENCES

Abate, A., Lanteri, V., Marcolongo, L., Solimei, L., & Maspero, C. (2023). Evaluation of Masticatory Muscles in Adult Patients with Maxillary Hypoplasia Treated with Surgically Assisted Rapid Maxillary Expansion (SARME): A Retrospective Study. *J Clin Med, 12*(2). doi:10.3390/jcm12020607

Aktop, S., Gönül, O., Garip, H., & Göker, K. (2015). Surgically assisted maxillary expansion. . *In A Textbook of Advanced Oral and Maxillofacial Surgery Volume 2. IntechOpen.*

Babacan, H., Sokucu, O., Doruk, C., & Ay, S. (2006). Rapid maxillary expansion and surgically assisted rapid maxillary expansion effects on nasal volume. *Angle Orthod, 76*(1), 66-71. doi:10.1043/0003-3219(2006)076[0066:RMEASA]2.0.CO;2

Berkun, O., Findik, Y., Akpinar, O., Ay, Z. Y., & Baykul, T. (2022). Evaluation of RANK, RANKL and OPG Levels in Gingival Crevicular Fluid After Surgically Assisted Rapid Maxillary Expansion. *J Maxillofac Oral Surg, 21*(2), 487-492. doi:10.1007/s12663-020-01481-1

Bin Dakhil, N., & Bin Salamah, F. (2021). The Diagnosis Methods and Management Modalities of Maxillary Transverse Discrepancy. *Cureus, 13*(12), e20482. doi:10.7759/cureus.20482

Bortolotti, F., Solidoro, L., Bartolucci, M. L., Incerti Parenti, S., Paganelli, C., & Alessandri-Bonetti, G. (2020). Skeletal and dental effects of surgically assisted rapid palatal expansion: a systematic review of randomized controlled trials. *Eur J Orthod, 42*(4), 434-440. doi:10.1093/ejo/cjz057

Carvalho, F. S. R., Studart Soares, E. C., Ferreira Barbosa, D. A., de Araujo Mouta, A. E., Marinho Bezerra, T. M., Ribeiro, T. R., & Gurgel Costa, F. W. (2019). Does surgically assisted rapid maxillary expansion associated with pterygomaxillary disjunction result in changes in mandibular position? A PROSPERO-compliant systematic review of the literature. *J Craniomaxillofac Surg, 47*(7), 1046-1053. doi:10.1016/j.jcms.2019.02.009

Chhatwani, S., Schudlich, K., Mohlhenrich, S. C., Pugachev, A., Bicsak, A., Ludwig, B., . . . Bonitz, L. (2021). Evaluation of symmetry behavior of surgically assisted rapid maxillary expansion with simulation-driven targeted bone weakening. *Clin Oral Investig, 25*(12), 6717-6728. doi:10.1007/s00784-021-03958-w

Feng, Z., Si, M., Fan, H., Zhang, Y., Yuan, R., & Hao, Z. (2023). Evolution, current status, and future trends of maxillary skeletal expansion: a bibliometric analysis. *Clin Oral Investig, 28*(1), 14. doi:10.1007/s00784-023-05430-3

Gogna, N., Johal, A. S., & Sharma, P. K. (2020). The stability of surgically assisted rapid maxillary expansion (SARME): A systematic review. *J Craniomaxillofac Surg, 48*(9), 845-852. doi:10.1016/j.jcms.2020.07.003

Gurler, G., Akar, N. K., Delilbasi, C., & Kacar, I. (2018). Skeletal changes following surgically assisted rapid maxillary expansion (SARME). *Eur Oral Res, 52*(2), 94-98. doi:10.26650/eor.2018.465

Huang, X., Han, Y., & Yang, S. (2022). Effect and stability of miniscrew-assisted rapid palatal expansion: A systematic review and meta-analysis. *Korean J Orthod, 52*(5), 334-344. doi:10.4041/kjod21.324

Jensen, T., & Rodrigo-Domingo, M. (2017). Surgically assisted rapid maxillary expansion (SARME) with or without intraoperative releasing of the nasal septum. *Oral Surg Oral Med Oral Pathol Oral Radiol, 123*(3), e85-e90. doi:10.1016/j.oooo.2016.10.003

Karabiber, G., & Yilmaz, H. N. (2023a). Does unilateral surgically assisted rapid maxillary expansion (SARME) lead to perinasal asymmetry? *J Orofac Orthop, 84*(1), 1-9. doi:10.1007/s00056-021-00333-y

Karabiber, G., & Yilmaz, H. N. (2023b). Three-dimensional evaluation of the temporomandibular joints after unilateral surgically assisted rapid maxillary expansion in adults: A preliminary retrospective study. *J Oral Rehabil, 50*(12), 1432-1438. doi:10.1111/joor.13576

Khan, M. K., Sharma, D. S., & Jindal, M. K. (2023). Unusual systemic and nondental effects of maxillary expansion therapy: A comprehensive and updated review of literature. *J Orthod Sci, 12*, 38. doi:10.4103/jos.jos_25_23

Kurt, G., Altug, A. T., Turker, G., Kilic, B., Kilic, E., & Alkan, A. (2017). Effects of Surgical and Nonsurgical Rapid Maxillary Expansion on Palatal Structures. *J Craniofac Surg, 28*(3), 775-780. doi:10.1097/SCS.0000000000003468

Laino, L., Troiano, G., Dioguardi, M., Perillo, L., Laino, G., Lo Muzio, L., & Cicciu, M. (2016). Patient Discomfort During and After Surgically Assisted Rapid Maxillary Expansion Under Local Anaesthesia. *J Craniofac Surg, 27*(3), 772-775. doi:10.1097/SCS.0000000000002535

Landes, C. A., Laudemann, K., Petruchin, O., Revilla, C., Seitz, O., Kopp, S., . . . Sader, R. A. (2012). Advantages and limits of 3-segment (paramedian) versus 2-segment (median) surgically assisted rapid maxillary expansion (SARME). *Oral Surg Oral Med Oral Pathol Oral Radiol, 113*(1), 29-40. doi:10.1016/j.tripleo.2011.01.013

Laudemann, K., Petruchin, O., Mack, M. G., Kopp, S., Sader, R., & Landes, C. A. (2009). Evaluation of surgically assisted rapid maxillary expansion with or without pterygomaxillary disjunction based upon preoperative and post-expansion 3D computed tomography data. *Oral Maxillofac Surg, 13*(3), 159-169. doi:10.1007/s10006-009-0167-3

Liu, K., Wei, H., Dai, J., & Wang, X. (2020). Does Nasal Cavity Enlargement Associated With Respiratory Function Improvement After Surgically Assisted Rapid Maxillary Expansion? *J Craniofac Surg, 31*(3), 829-831. doi:10.1097/SCS.0000000000006245

Loriato, L., & Ferreira, C. E. (2020). Surgically-assisted rapid maxillary expansion (SARME): indications, planning and treatment of severe maxillary deficiency in an adult patient. *Dental Press J Orthod, 25*(3), 73-84. doi:10.1590/2177-6709.25.3.073-084.bbo

Magnusson, A., Bjerklin, K., Nilsson, P., & Marcusson, A. (2009). Surgically assisted rapid maxillary expansion: long-term stability. *Eur J Orthod, 31*(2), 142-149. doi:10.1093/ejo/cjn074

Marino Merlo, M., Quiroga Souki, B., Nieri, M., Bonanno, A., Giuntini, V., McNamara Jr, J. A., & Franchi, L. (2024). Comparison of the effects on facial soft tissues produced by rapid and slow maxillary expansion using stereophotogrammetry: a randomized clinical trial. . *Progress in Orthodontics, 25*(1), 1.

Martin, A., Oyallon, M., Perrin, J. P., Durand, T., Deumier, L., Corre, P., . . . Bertin, H. (2023). Alveolar bone changes after tooth-borne surgically assisted rapid maxillary expansion: A three-dimensional study. *J Stomatol Oral Maxillofac Surg, 124*(1S), 101331. doi:10.1016/j.jormas.2022.11.007

Mubeen, S., Shah, D. K., Cronin, A. J., & Sharma, P. K. (2023). Non-surgical management of maxillary transverse discrepancies in the orthognathic patient: a review. *Frontiers of Oral and Maxillofacial Medicine.*, 1-10.

Nada, R. M., Fudalej, P. S., Maal, T. J., Berge, S. J., Mostafa, Y. A., & Kuijpers-Jagtman, A. M. (2012). Three-dimensional prospective evaluation of tooth-borne and bone-borne surgically assisted rapid maxillary expansion. *J Craniomaxillofac Surg, 40*(8), 757-762. doi:10.1016/j.jcms.2012.01.026

Oliveira, T. F., Pereira-Filho, V. A., Gabrielli, M. A., Goncales, E. S., & Santos-Pinto, A. (2016). Effects of lateral osteotomy on surgically assisted rapid maxillary expansion. *Int J Oral Maxillofac Surg, 45*(4), 490-496. doi:10.1016/j.ijom.2015.11.011

Pereira, P. A. A., Canellas, J. V., Souza, R. B., Tiwana, P. S., Medeiros, P. J., & Ritto, F. G. (2022). Three-segment versus 2-segment surgically assisted rapid maxillary expansion. *Oral Surg Oral Med Oral Pathol Oral Radiol, 133*(3), 264-270. doi:10.1016/j.oooo.2021.06.002

Reinbacher, K. E., Wallner, J., Pau, M., Feichtinger, M., Karcher, H., Quehenberger, F., & Zemann, W. (2013). Surgically assisted rapid maxillary expansion: feasibility of not releasing the nasal septum. *Int J Oral Maxillofac Surg, 42*(3), 321-325. doi:10.1016/j.ijom.2012.09.021

Rutili, V., Mrakic, G., Nieri, M., Franceschi, D., Pierleoni, F., Giuntini, V., & Franchi, L. (2021). Dento-skeletal effects produced by rapid versus slow maxillary expansion using fixed jackscrew expanders: a systematic review and meta-analysis. *Eur J Orthod, 43*(3), 301-312. doi:10.1093/ejo/cjaa086

Rutili, V., Nieri, M., Franceschi, D., Pierleoni, F., Giuntini, V., & Franchi, L. (2022). Comparison of rapid versus slow maxillary expansion on patient-reported outcome measures in growing patients: a systematic review and meta-analysis. *Prog Orthod, 23*(1), 47. doi:10.1186/s40510-022-00440-5

Sant'Ana, L. F., Pinzan-Vercelino, C. R., Gurgel, J. A., & Carvalho, P. S. (2016). Evaluation of surgically assisted rapid maxillary expansion with and without midpalatal split. *Int J Oral Maxillofac Surg, 45*(8), 997-1001. doi:10.1016/j.ijom.2016.03.005

Seeberger, R., Kater, W., Davids, R., & Thiele, O. C. (2010). Long term effects of surgically assisted rapid maxillary expansion without performing osteotomy of the pterygoid plates. *J Craniomaxillofac Surg, 38*(3), 175-178. doi:10.1016/j.jcms.2009.07.003

Seidita, F., de Azambuja Carvalho, P. H., Dos Santos, J. C., Dell'Aversana Orabona, G., Califano, L., Gabrielli, M. F. R., & Filho, V. A. P. (2022). Nasal Septal Deviation After Surgically Assisted Rapid Maxillary Expansion. *J Maxillofac Oral Surg, 21*(3), 765-771. doi:10.1007/s12663-021-01529-w

Sygouros, A., Motro, M., Ugurlu, F., & Acar, A. (2014). Surgically assisted rapid maxillary expansion: cone-beam computed tomography evaluation of different surgical techniques and their effects on the maxillary dentoskeletal complex. *Am J Orthod Dentofacial Orthop, 146*(6), 748-757. doi:10.1016/j.ajodo.2014.08.013

Xi, T., Laskowska, M., van de Voort, N., Ghaeminia, H., Pawlak, W., Berge, S., & Maal, T. (2017). The effects of surgically assisted rapid maxillary expansion (SARME) on the dental show and chin projection. *J Craniomaxillofac Surg, 45*(11), 1835-1841. doi:10.1016/j.jcms.2017.08.023

Zambon, C. E., Ceccheti, M. M., Utumi, E. R., Pinna, F. R., Machado, G. G., Peres, M. P., & Voegels, R. L. (2012). Orthodontic measurements and nasal respiratory function after surgically assisted rapid maxillary expansion: an acoustic rhinometry and rhinomanometry study. *Int J Oral Maxillofac Surg, 41*(9), 1120-1126. doi:10.1016/j.ijom.2011.12.037

Zandi, M., Miresmaeili, A., Heidari, A., & Lamei, A. (2016). The necessity of pterygomaxillary disjunction in surgically assisted rapid maxillary expansion: A short-term, double-blind, historical controlled clinical trial. *J Craniomaxillofac Surg, 44*(9), 1181-1186. doi:10.1016/j.jcms.2016.04.026

Zeng, W., Yan, S., Yi, Y., Chen, H., Sun, T., Zhang, Y., & Zhang, J. (2023). Long-term efficacy and stability of miniscrew-assisted rapid palatal expansion in mid to late adolescents and adults: a systematic review and meta-analysis. *BMC Oral Health, 23*(1), 829. doi:10.1186/s12903-023-03574-y

Zupan, J., Ihan Hren, N., & Verdenik, M. (2022). An evaluation of three-dimensional facial changes after surgically assisted rapid maxillary expansion (SARME): an observational study. *BMC Oral Health, 22*(1), 155. doi:10.1186/s12903-022-02179-1