VOLUME 36 | NUMBER 2 | Summer 2025

International Journal of Orthodontics

Published Quarterly by the
International Association for Orthodontics

In this Issue:

Author Guidelines

MANUSCRIPT SUBMISSION

Manuscripts are to be submitted electronically at www.editorialmanager.com/iaortho. If the manuscript is written in a language other than English, the author(s) must submit an English translation. The author may also submit a copy in his or her native language that will published in the online version only with a mention in the printed issue that the article is available online in his or her own language. The manuscript must be original and submitted exclusively to IJO.

The *Journal* invites authors to submit:

- Clinical reports
- Technique articles
- Review articles
- Case reports

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Abstract. Must include a short abstract no more than 50 words that describe the significance of the article.

Keywords. Must include keywords to help categorize the article.

Length. Manuscript should be no longer than 15 double-spaced pages, excluding figures and illustrations.

Tooth Numbering. The numbering of teeth should be international numbering. (US numbering can be added and put in parentheses.)

Non-English Manuscripts. Authors are encouraged to submit the manuscript in languages other than English for posting on the IAO website. A mention will be added to the English version published in the International Journal of Orthodontics, directing readers online for other translations.

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Book:

2. Fonder AC. The Dental Physician. 2nd ed. Rock Falls, IL; Medical Dental Arts; 1985:25-82.

World Wide Web site:

3. Health Care Financing Administration. 1996 statistics at a glance. Available at: http://www.hcfa.gov/stats/stathili.htm". Accessed Dec. 2, 1996.

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International Journal of Orthodontics
750 North Lincoln Memorial Drive, #422
Milwaukee, WI, USA 53202
Phone 414-272-2757, Fax 414-272-2754
E-mail: worldheadquarters@iaortho.org

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International Journal of
Orthodontics

SUMMER 2025 ■ VOLUME 36 ■ NUMBER 2

FEATURES

Departments

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Hosted by IAO Ontario Section

Friday October 3, 2025

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Guest Speakers & Topics

Effective Case Finishing for Orthodontics Utilizing Wire Bending

Dr. Mike Lowry, DDS

Learning Outcomes:

• Learn solutions to basic tooth orientation problems using wire bending skills

• Explore common problems at the end of cases and how to address them

• How to start with the end in mind

Dr. Lowry has been in practice for over 36 years and has been involved in orthodontics since taking his first course with Dr. Rondeau in 1987. Over the time since then, Dr. Lowry has studied with Rondeau Seminars, United States Dental Institute, various instructors teaching TMD and facial pain, facial beauty institute, and the IAO instructors institute. He currently holds the designation of Master Senior Instructor with the IAO. Dr. Lowry has served as president of the IAO and was on the executive committee for 5 years. He is currently retired from private practice but his practice consisted of roughly 30 % orthodontics and he treated all phases of orthodontics including orthopedics, TMD, and sleep. Dr. Lowry has achieved the level of Diplomat and has served as chair of the International Board of Orthodontics and is still a member. As such, he is involved in the IAO Professional Advancement program and is serving as an examiner for students involved in undertaking that process. He is also a reviewer for the peer review program for IAO journal articles awaiting submission. Until recently, Dr. Lowry assisted Dr. Rondeau with the level 1 courses in Vancouver, Calgary and Edmonton and other locations as needed. He is the mentor for two study clubs in Alberta, one in Vancouver and one in Saskatchewan.

Note: All participants encouraged to bring bird beak pliers

Conflict of Interest: None

Development of Occlusion from a Pediatric Perspective”

Dr. Gajanan Kulkarni, DDS

Learning Outcomes:

• Modifying the influence of the following on developing dentition

- o Dental Caries
- o Non nutritive oral habits
- o Trauma

• Better understanding of the most common pediatric dental problems and their management for the optimal development of occlusion

Dr. Gajanan Kulkarni is a tenured Associate Professor of Dentistry at the University of Toronto where he has been working since 1998. His duties as a full-time academic include teaching of undergraduate, graduate and post-graduate students. Dr. Kulkarni also maintains an active research program. His main research interests are in fields related to Pediatric Dentistry.

Complimenting his academic career, Dr. Kulkarni practices pediatric dentistry with a special focus on children with special needs.

Conflict of Interest: None

Utilizing Orthodontic Proficiency with General Dentistry for Effective Solutions

Dr. Lee Willis, DDS

Learning Outcomes:

• Problem-solving multiple different treatment plans for issues related to the underdeveloped Maxilla

• Utilizing new techniques in retrieving impacted canines

• Learning how to do in-house simple Ortho lab work, saving thousands of dollars each year

• Knowing when to use Porcelain over Ortho and when to use Ortho over Porcelain

• Improving your case presentations and acceptance with your patients

Dr. Lee Willis DDS IBO graduated from the University of the Pacific School of Dentistry in 1996. In 2001, Dr. Willis decided to learn more about dentistry and started his journey into the study of orthodontics. It wasn’t long before the theories of TMD grabbed his full attention. Dr. Willis practices in Roseburg, Oregon doing mostly TMD dentistry and orthodontics with a special interest in TMD. Dr. Willis has severed 10 years on the International Board of Examiners and as President of the IBO. Currently Dr. Willis is the President Elect for the IAO and has been a member of the IAO since 2001. When Dr. Willis isn’t drilling and filling he enjoys his time restoring old muscle cars for fun.

Conflict of Interest: None

Orthopedic Expansion and Orthodontics: Maximizing Growth, Development, and IQ potential

Dr. Timothy Adams, DDS, D.ACSDD

Learning Outcomes:

Attendees will learn to use a lightwire one block appliance to address:

• Posture

• Airway

• Tongue position

• Neurology

Dr. Timothy Adams is a renowned leader in the dental community, with over 35 years of experience in the field of dentistry. Dr. Adams is known for his expertise in cosmetic dentistry, neuromuscular dentistry, occlusion, TMJ, sleep, and his focus on fusing form, function, and aesthetics. He believes that beauty must align with function, and changes in the bite can rejuvenate or have the opposite effect if an inexperienced doctor doesn’t understand the importance of this relationship. Dr. Adams is passionate about improving health and wellness through improved craniofacial function, jaw joint function, sutural homeostasis, and breathing. He believes the body is interconnected, and changes in one part of the body can impact other parts. Cranial strains and patterns of the cranial bones in our head affect jaw positions that directly affect our head and neck posture, TMJ, cervical stability, spinal column, tongue position. breathing and the autonomic nervous system.

Conflict of Interest: Lecture Sponsored by BioRESEARCH

Editorial

Dr. Rob Pasch
Editor

As summer continu in much of the world, we are reminded of nature's peak expression—long days, abundant light, and the ripening of what was once only seed and promise.

In orthodontics, too, this season mirrors our work: nurturing potential, guiding growth, and bringing carefully cultivated plans into full fruition.

In recent years, advances in technology have given our profession unprecedented precision. From AI-assisted diagnostics and 3D imaging to digitally guided appliances and micro-force biomechanics, the tools in our hands are more refined than ever. Yet, as with a garden, tools alone are not enough. Success lies in the skill, patience, and ethical stewardship of the clinician who wields them.

This issue highlights several clinical pearls—subtle adjustments in force application, timing, and interdisciplinary collaboration—that can transform a patient's journey. Whether integrating pediatric ENT input for airway optimization, or fine-tuning elastic wear protocols with app-based compliance tracking, these innovations are most powerful when paired with empathy and clear communication.

We must also consider our broader responsibility. As specialists, we are not only aligning teeth but supporting neurodevelopment, breathing health, and the confidence of the next generation. Our decisions ripple into public health: early interventions can reduce the need for complex surgical corrections, and patient education empowers families to take ownership of long-term outcomes.

Ethics, too, remain our compass. In a time of rapid commercial expansion and shifting treatment models, we must guard against overtreatment, under-disclosure, and the commodification of care. True orthodontic excellence balances innovation with integrity, evidence with artistry, and business realities with the well-being of those we serve.

This summer, let us embrace the season's lesson: growth is both art and science. It demands the right environment, careful monitoring, and respect for the natural pace of development. In doing so, we not only straighten smiles—we shape futures.

May the ideas in these pages inspire you to step into the warmth of possibility, ready to cultivate the best in your patients, your practice, and yourself. I have a request to all who read this, and the ask is to please write and submit articles or case reports to the journal, for the journal is YOUR journal and you can make it reflect what is important to you today and in doing so making the journal better for everyone, also send the journal to your friends and share the knowledge. It is a very good feeling to see your name in print, besides your patients will appreciate it as well.

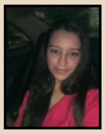
Yours for accredited GP orthodontic education and better patient care

I remain
Respectfully,
Dr. Rob Pasch DDS MSc IBO General Practitioner.
Summer, 2025

A Multiple Helical Wire for Multiple Impactions: MH Wire

by Snigdha Kumar, MDS; Dipti Shastri, MDS; and Dr. Gulshan Kumar Singh, MDS

AUTHORS



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Abstract:

When two impacted teeth are adjacent, it can be tedious to align them one by one. A novel MH wire does simultaneous disimpaction and space management. This appliance has optimum range of function.

Keywords: impacted teeth; multiple impactions; disimpactions; orthodontic treatment; biomechanics; loop mechanics

Conflict of Interest: None

Introduction

Impacted teeth are those that have delayed eruption time or that are not expected to erupt completely based on clinical and radiographic assessment.[1] However, multiple impacted teeth is a rare finding and often associated with systemic diseases or some rare syndromes.[2,3] It requires tedious biomechanics to resolve. Therefore, we created a Multiple Helical wire for simultaneous disimpaction of two adjacent teeth as well as to create space. It is essential to design the appliance carefully for efficient and desired movement.

Case

A 16-year-old male patient reported with a chief complaint of facial deformity and experiencing tenderness while chewing food. On examination, there were multiple retained deciduous teeth in the maxillary and mandibular arch, severe crowding present in the maxillary arch, multiple missing teeth, high-arched palate, skeletal anterior crossbite, reverse overjet, increased curve of spee, and bilateral Class III molar relation. Upon radiographic assessment, all four canines were impacted, and first and second premolars were impacted in the second and third quadrants. (Figure 1A-C)

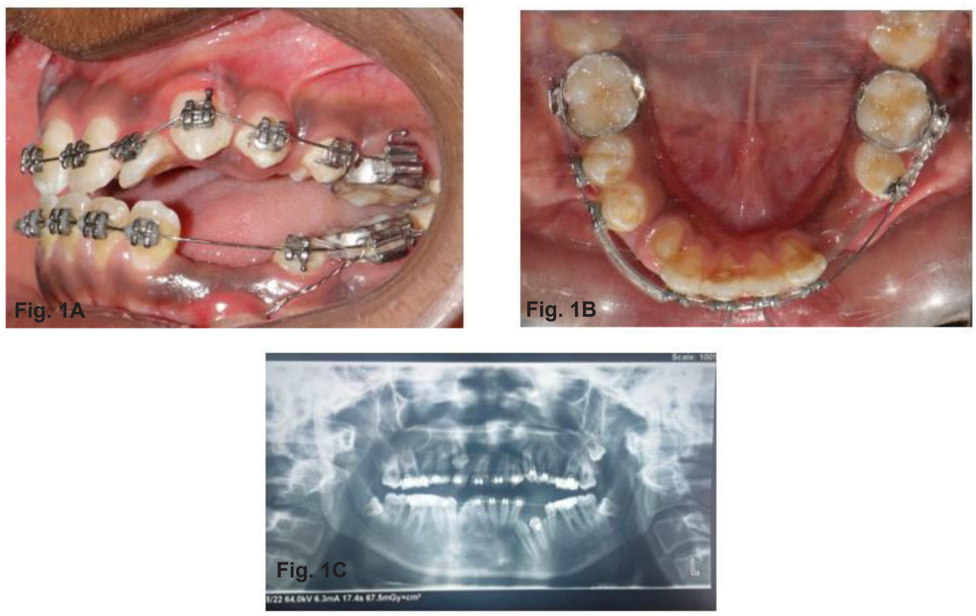

Fig 1 (a,b) **Intra-oral views- left lateral and occlusal showing missing 33 and 34**
(c)- Orthopantomograph showing impacted 33 and 34

*This article has been peer reviewed

Technique

The MH wire has two small size open vertical loops with helices, placed adjacent to each other, incorporated in an overextended open U loop (Figure 2A).

The vertical loops are used to give traction to the attachments on impacted teeth. The helices at the apex increase the range of the wire. The overextended loop creates minimal space or can be used to maintain space (Figure 2A).

It can be fabricated with 0.017*0.025" TMA (Ormco Co.) or 0.016" SS (A.J. Wil-cock, Whittlesea, Victoria, Australia). Two small vertical loops were bent with helices. It is fabricated slightly overextended between the adjacent anchor segments (lateral incisor and second premolar in this case) i.e. the passive state. This step is optional if further welcome preparation is not required. Thus, it is an overextended open vertical loop as illustrated (Figure 2B). Adjacent segments are ligated in a figure-of-eight tie before final ligation to counteract any reciprocal forces (Figures 3A, 3B). The loop is compressed when ligated (Figures 3A, 3B).

Discussion

Any loop can be an open or closed loop. An open or continuous loop when activated by compressing the legs will tend to push horizontal extensions apart, increasing the arch length.[4]

It has a two-way activation :

1. Engaging it in the bracket slots to gain space.
2. Tying ligature wire from the helices to attachments bonded on impacted teeth for its traction.

Advantages of MH Wire:

1. Harness the springiness and low forces offered by TMA and Australian wire[5]
2. Individual traction to 33 and 34 to erupt through alveolus.
3. Simultaneous disimpaction of multiple impacted teeth
4. Simultaneous space creation and maintenance will take place.
5. It can be fabricated as a spring as well as bent in a continuous wire.


Fig. 2A

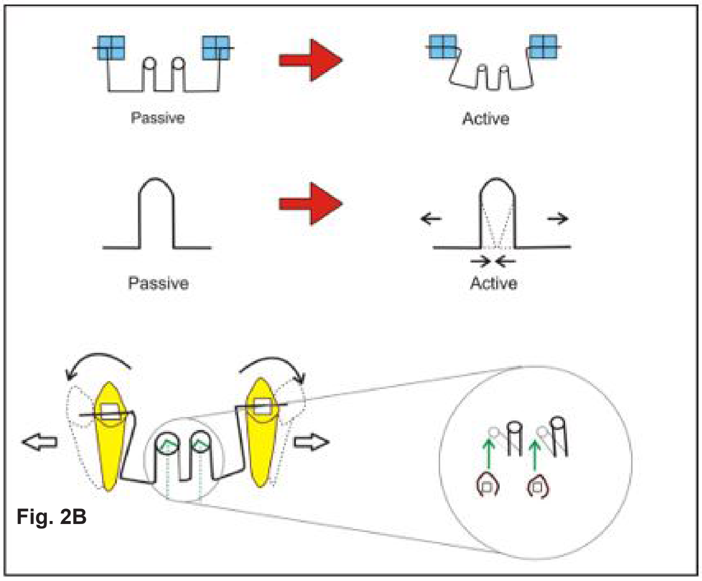

Fig. 2B


Fig. 3A

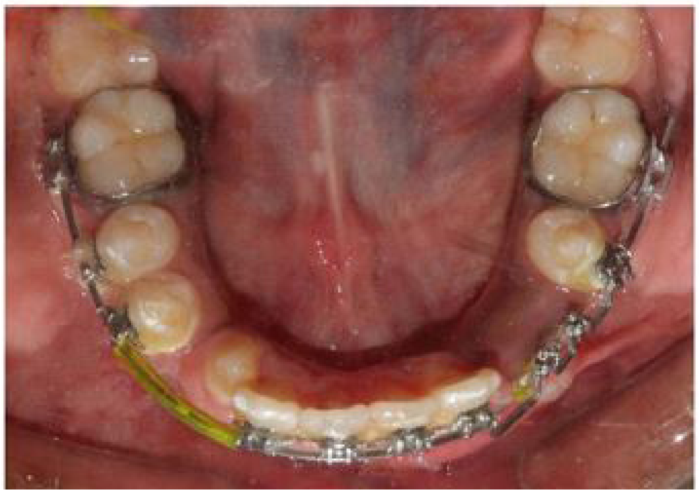

Fig. 2A: Force system produced by MH wire.
Fig. 2B: llustration

Fig. 3A and 3B: Intra-oral views
Left lateral and occlusal showing final ligation of MH wire

All patient photos used with signed consent

Disadvantages of MH Wire:

1. Statistically indeterminate system
2. Technique Sensitive
3. As multiple units are being dis-impacted, arch distortion can take place.

The springiness of TMA and Australian wire allows significant bending of the loops in a downward direction, which in turn provides vertically upward deactivating vector to both the impacted teeth. Additionally, a module can also be utilized for harvesting elastic force. After three months of active mechanics, canine and premolar erupted in oral cavity and later continuous wire was ligated for alignment (Figures 4A-C).

Fig 4A and 4B: Intra-oral views – left lateral and occlusal showing 33 and 34 erupted into oral cavity
Fig. 4C: Orthopantomograph showing 33 and 34 present in the mandibular arch

Conclusion

This assembly is a simple fabrication which can be utilized for multiple adjacent impactions. It saves the time and effort of the clinician when difficult biomechanics are involved for such cases.

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TIPS FROM THE EXPERIENCED

Mulligan Mechanics Part I

By Dr. Adrian J. Palencar, MUDr, MAGD, IBO, FADI, FPFA, FICD

The author was introduced to Mulligan Mechanics in late eighties, while attending one of Dr. Mulligan's presentations, "Common Sense Mechanics." After attending numerous Dr. Mulligan's lectures, the author embraced his philosophy of biomechanics and applied it to his everyday practice.

Dr. Thomas F. Mulligan (1933 – 2023) was a renown orthodontist, mentor and educator from Phoenix, Arizona. He authored and published 25 articles, lectured in 32 countries, and authored and published three books, "Common Sense Mechanics in Everyday Orthodontics." Dr. Mulligan simplified biomechanics and deftly explained Forces, Moments, Moment to force ratio, Center bend, Off-center bends, and Static Equilibrium.

Static Equilibrium

Requirements for Static Equilibrium: The sum of all horizontal, vertical forces and moments around common point equals ZERO.

The following image explains the basic principles of the moments and forces in Mulligan mechanics. The author and some of his course attendees had difficulties at the beginning to embrace his philosophy.

Let us analyze the Static Equilibrium on the teeter-totter:

First example on the image: two children, the same weight - 25 kg decided to play on the teeter-totter. Both sat down at the end of the board – 100 cm from the fulcrum and the teeter-totter was in Static Equilibrium. After the activation (one side pushing off the ground), each side had a potential of 2,500 kg/cm (25x100 - force x distance) of downward moment of the force.

Second example on the image: the child on the right side left, and their older sibling came to play. He sat down, and the board went down on his side. Why did this happen? Both children sit 100 cm from the fulcrum, however one on the left produces 2,500 kg/cm (25x100), the other on the right side 5,000 kg/cm (50x100 - force x distance) moment of the force. The Static Equilibrium was violated.

Third example on the image: The child on the right side studied physics in the high school, thus he decided to move closer to the fulcrum, and low and behold, they were in Static Equilibrium. Why did this happen? The smaller child produced 2,500 kg/cm of moment of the force and the larger child the same - 2,500 kg/cm moment of the force (50x50 – force x distance), ergo, they achieved the Static Equilibrium

What did we glean from this example?

The smaller weight (force) and larger distance (wire) equals to
The larger weight (force) and smaller distance (wire}

When we can not move the boulder with our hands (short distance), we take a long crowbar (long distance) to move it.

The same strength, only longer distance.

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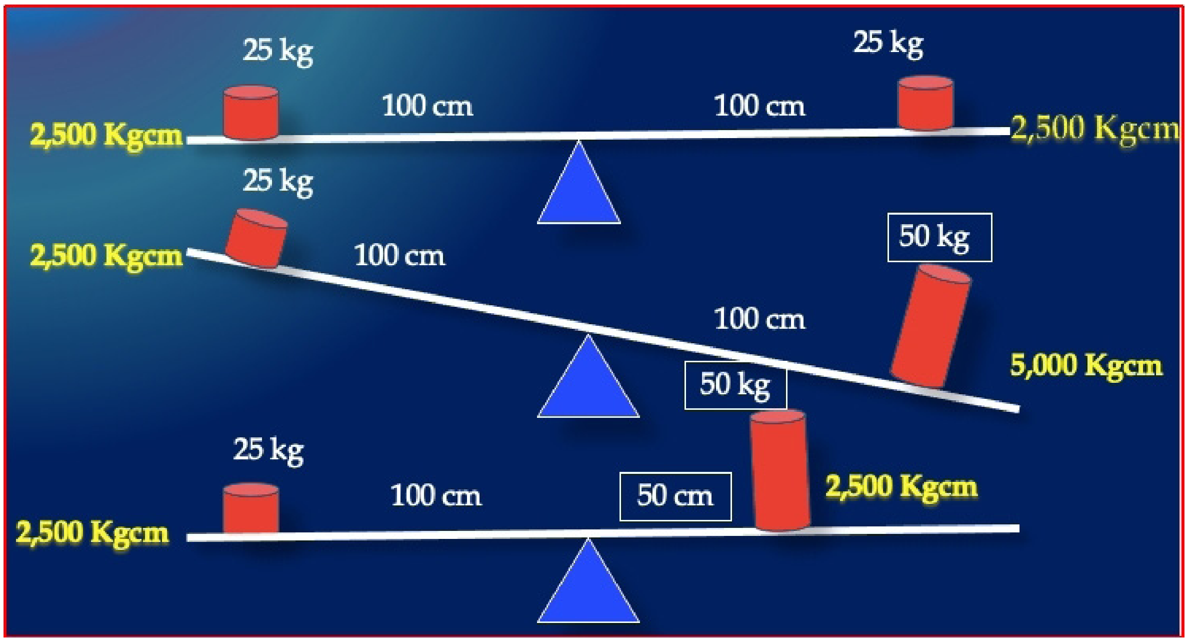

Impacted Teeth in the Mixed Dentition Phase: A Differentiated Interception

by Isabela de Castro Ribeiro;Anna Průchová Alves; Diogo de Azevedo Miranda, PhD; Flávio Ricardo Manzi, PhD; and Izabella Lucas de Abreu Lima, PhD

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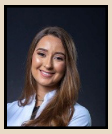

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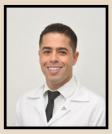

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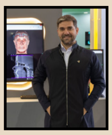

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Dr. Izabella Lucas de Abreu Lima
PhD, Pontifical Catholic University of Minas Gerais, Belo Horizonte, Minas Gerais, Brazil

Abstract

Introduction: Teeth eruption is a physiological process characterized by a sequence of events that occur so that primary teeth reach the oral cavity and are later replaced by permanent teeth. In some situations, such as dental traumas, this can lead to the development of problems such as eruption deviations and impacted teeth, consolidating important malocclusions

Objectives: Using a case report of a child patient who had impaction of teeth 21 and 23 with trauma-associated etiology to show the importance of an individualized and multidisciplinary treatment plan that implements a successful and differentiated alternative for treating impacted teeth.

Conclusion: After the implementation of a successful and individualized alternative for traction of impacted teeth for the patient's well-being and growth, there was significant improvement in her quality of life with the achievement of the proposed treatment goals.

Keywords: Impacted tooth. Malocclusion.

Conflict of Interest: None

Introduction

Monitoring the development of dental occlusion is responsibility of the orthodontist.[1] The appropriate development will help with the acquisition of a healthy functional and aesthetic permanent denture.[2] Several events will occur and characterize three distinct moments of occlusion development: the primary, mixed, and permanent dentures.[3]

Eruption of primary teeth usually begins approximately 6 months after child's birth and all deciduous teeth are erupted before the child turns 3 years-old.[4] The mixed dentition phase is characterized by the presence of deciduous and permanent teeth in the oral cavity. In some regions, deciduous teeth are replaced by permanent teeth. This process can take a few years and is characterized by distinct periods.[5] The most frequent eruption sequence of permanent teeth in maxillary region is first molars, central and lateral incisors, first premolars, second premolars, canines, and the second molars. In the mandible, the frequent eruption sequence is first molars, central and lateral incisors, first premolars, canines, second premolars, and the second molars.[3]

As observed, canines are almost the last teeth to arrive in maxilla. When comparing to the others teeth, canines take twice as long to complete their eruption, making them more likely go through changes in the normal eruption trajectory.[6] The mineralization process begins before the first molars and incisors erupt.6 In addition, permanent canines are the most susceptible teeth to suffer impaction and lack of space,[3] resulting in a frequently observed clinical problem, which is ectopic eruption or buccal or palatal impaction.[6] In relation to the upper central incisors, the most common cause of the impaction is the presence of a supernumerary tooth.[7]

The etiology of dental impactions might be associated with primary causes, as root resorption of the primary tooth, deciduous teeth trauma, unavailability of space in the arch, permanent teeth germs rotation, root apices premature closure, canine eruption in cleft palate areas. Impactions can also be associated with secondary causes, such as abnormal muscle pressure, febrile illnesses, endocrine disorders, and vitamin D deficiency.[8] In addition, factors such as mechanical interference and a deflection that alters the normal course can also prevent teeth from erupting.[7] The most common causes are locals and can be the result of a combination of more than one factors.[9] Traumas may interfere with the odontogenesis of permanent teeth. Different malformations may occur as a slight disturbance in the mineralization of enamel to a sequestration of the entire

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tooth germ may lead to abnormality in the path of eruption and may result in impaction or ectopic eruption.[10]

Treatment of ectopic eruption and impaction of permanent teeth, mainly maxillary canines, are of great interest in orthodontics. Therefore, the aim of this paper is to describe a unique and successful approach of a patient with an impacted maxillary central incisor and maxillary canine after trauma.

Case Report

Informed consent was obtained. An 8-year, 9-month-old female patient was brought in by her aunt, seeking orthodontic treatment. The patient mentioned that she was being bullied at school due to her unpleasant smile and complained that her front teeth were crowded. Her medical story was within normal limits. According to her aunt, some years ago the patient had suffered a trauma in the anterior teeth, but as there were no complaints by the patient, she did not seek for a pediatric dentist and had not undergone a radiographic follow-up. In addition, the patient had adequate oral hygiene and had never undergone orthodontic treatment.

Extraoral evaluation revealed a symmetric face, passive lip sealing, normal smile line, proportional facial thirds, and a straight facial profile. Furthermore, the patient presented compromised smile esthetics with a possible impaction of the left upper central incisor and left upper canine with etiology associated with trauma (Fig 1).

Fig. 1: Initial extraoral photographs

Intraoral analysis showed she was in the mixed dentition phase, second transitional period. She presented an Angle Class II malocclusion first division combined with an anterior open bite and impacted left upper central incisor and canine, left upper lateral incisors rotated and horizontal. The left upper central incisor and upper canine were not present in the arch. There was a transverse maxillary deficiency, and a tapered upper arch form, especially in the anterior region (Fig 2).

Fig. 2: Initial intraoral photographs.

Panoramic radiograph (Fig 3) confirmed the presence of all permanent teeth, a mixed dentition, and in the region of teeth 21, 22 and 23, the image suggested proximity and unfavorable positioning of those germs, confirmed by periapical radiography (Fig 4). In addition, tooth 21 had a root dilaceration (Fig 3). Cephalometric evaluation revealed a Class II skeletal malocclusion (ANB = 9º) with a protruded maxilla (SNA= 89º), a properly positioned mandible (SNB= 80º), a normal body position of the maxillary incisors, and the mandibular incisors were significantly proclined (Fig 5). In addition to the conventional exams, a cone-beam computed tomography of the maxilla was requested to identify the exact positioning of the impacted teeth. The tomographic images reinforced the diagnosis of root dilaceration of tooth 21 and mesialization of the crown of 22. The tooth 23 had the crown located buccally in relation to the root of tooth 22 and an intimate contact between the crown of 23 and the root of 22 was observed (Fig 6).

Fig. 3: Initial panoramic radiograph.

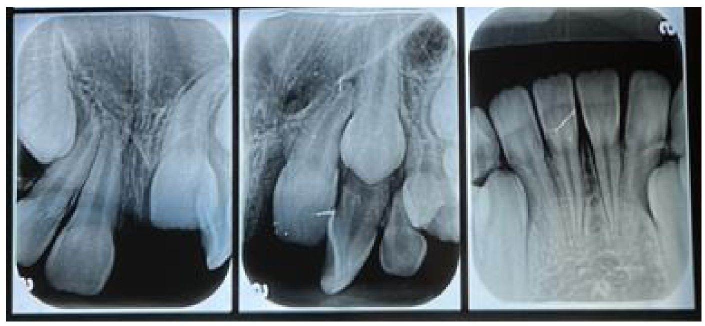

Fig. 4: Periapical radiographys

Fig. 5: Initial cephalometric profile radiograph

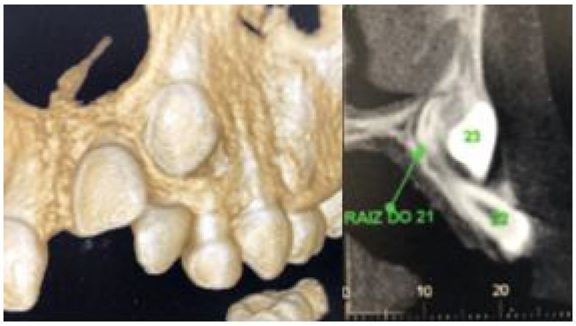

Fig. 6: Initial tomography. A)Reconstruction; B) Sagittal view

Treatment Objectives and Alternatives

The objectives of the first phase of this orthodontic treatment were to correct the transverse maxillary arch discrepancy, realize the traction of the impacted teeth, and then, in a second phase, fixed orthodontic appliances would be placed to achieve ideal esthetics and proper function. The treatment started with a Hyrax rapid palatal expander (RPE) that presented a welded handle next to the palatal region of tooth 11. The activation protocol was ¼ of a turn per day for 14 days when the lingual cusps of the maxillary molars were touching the buccal cusps of the mandibular molars, thus the patient's mother was oriented to stop activation. Three weeks after the RPE, tooth 21 began to erupt without any auxiliary procedure. After five weeks, a slight traction of tooth 22 was started using the handle in the palatal region of tooth 11 as anchorage (Fig 7).

Fig. 7: A) Illustration of occlusal view - traction of central tooth (force applied in the occlusal direction); B) Illustration of occlusal view – traction of lateral tooth (force applied in mesial direction, indicated by the red arrow.) Dot line: impacted tooth. Continuous line: teeth present in the oral cavity.

Five months after RPE and a slight traction of the 22, there was a swell in the region of tooth 23. The device was removed and a new tomographic image was requested. The new tomographic image revealed the tooth 22 was turned, the crown of tooth 23 had close contact with the root of 22, and the tooth 21 was semi-included, gyroverted, with its root in close contact with the crown of tooth 23 (Fig 8).

Tooth 63 was extracted and a traction accessory was bonded on 23. At the same time, a fixed transpalatal bar was installed with a buccal welded handle extended in the region of tooth 23. Initially, traction of 23 was performed by a horizontal vector, promoting the movement of 23 to the buccal region (Fig 9). Two months after the traction of the 23, its distal movement was started (Fig 10). The second phase of the treatment started four months later, when fixed Abzil (São José do Rio Preto – SP – Brazil) appliances were bonded in the upper arch, except for 13, which had not been erupted yet (Fig 11).

Fig. 8: Pre-traction tomography. A)Reconstruction; B) Sagittal view.

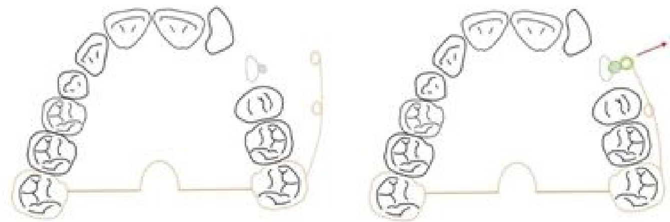

Fig. 9: A) Illustration of occlusal view – vestibularization of the canine (active spring); B) Illustration of occlusal view – vestibularization of the canine (active spring tied to the canine traction wire.) Force applied in buccal direction, indicated by the red arrow. Dot line: impacted tooth. Continuous line: teeth present in the oral cavity.

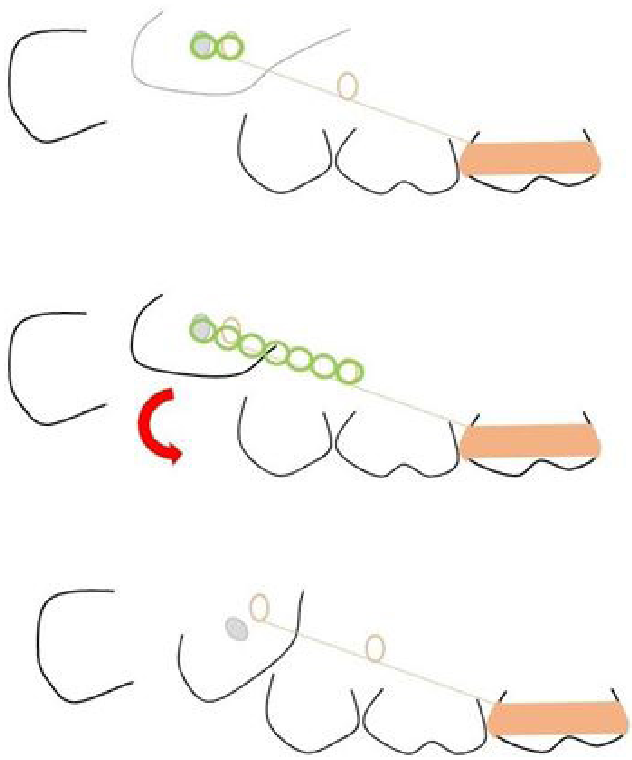

Fig. 10: A) Lateral illustration of the same mechanics from the previous figure; B) Illustration of the distalization of the canine's crown. The red arrow indicates de moment of strength from the crown to the distal direction; C) Illustration of the canine's crown distalized. Continuous line: teeth present in the oral cavity.

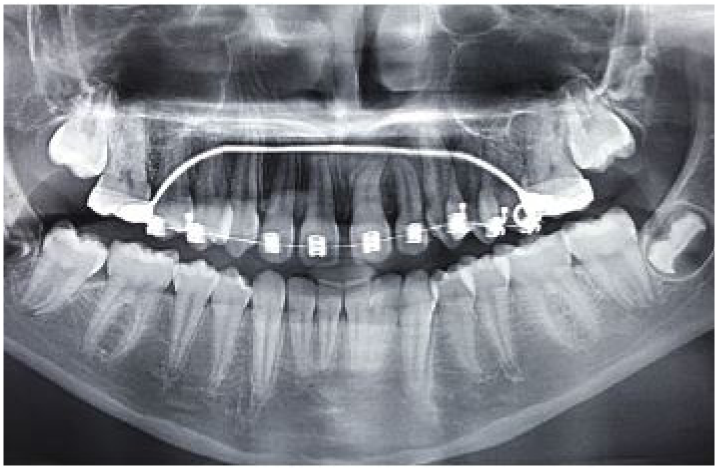

Fig. 11: Intermediary panoramic radiographic.

The treatment was interrupted five months after fixed appliance was partially bonded due to personal reasons and because the patient's chief complaint had been solved. Approximately two years after the interruption of treatment, the patient returned to continue the second phase of the orthodontic treatment. At the time of return, the patient was 12 years, six months old and her complaint was as follows: "I want to close the space between my front teeth." Her general health remained good, with no relevant medical history and satisfactory oral hygiene. The second phase of treatment consisted of maxillary and mandibular conventional fixed appliances and lasted one year.

Extraoral evaluation revealed a symmetric face, passive lip sealing, normal smile line, proportional facial thirds, and a convex facial profile. Furthermore, the patient presented a diastema between tooth 11 and 21 (Fig 9). Intraoral analysis showed she was in permanent dentition phase, with all permanent teeth in her mouth, except for third molars. She also presented an Angle Class I molar relationship and a Class II canine relationship. In occlusal analysis, "U"-shaped coordinated arches and a presence of slight gyroversions and diastema between teeth 11 and 21 were observed (Fig 10).

Panoramic radiography showed an intraosseous presence of the dental germs of left and right third molars in both arches. A root dilaceration of tooth 21, previously existing (Fig 11), was also observed. Cephalometric evaluation revealed a reduction in maxilla's protrusion (SNA from 89° to 85°) and mandibular position was practically maintained (SNB from 80° to 79°). The patient was still considered a skeletal Class II (ANB = 6°). Maxillary and the mandibular incisors were significantly proclined (Fig 12).

Fig. 12: IIntermediary extraoral photographs.

Treatment Results

Treatment goals were achieved after the two distinct phases of intervention, even with the interruption of treatment in the beginning of the second phase. Facially, passive lip sealing was maintained and there was a remarkable improvement of her smile esthetics due to the proper correction of her smile arch and the improved proportions of her buccal corridors. The facial profile was slightly convex, but it was improved by treatment and the patient's growth, when comparing to the beginning of treatment (Fig 13). Intraoral post-treatment examination revealed that an ideal occlusion was achieved with a Class I molar and canine relationship bilaterally, adequate overjet and overbite, coincident midlines, coordinated arches, absence of gyroversions, spaces, and crowding (Fig 14). Final panoramic radiograph evaluation showed no signs of root resorption, adequate overall alveolar bone levels, and appropriate root parallelism and the root dilaceration of tooth 21, previously existing (Fig 15). Also, at the end of the second phase, the patient presented a face with proportional vertical dimensions, as well as a normal smile line accompanied by the presence of passive lip seal.

Fig. 13: Intermediary extraoral photographs.

Fig. 14: Intermediary panoramic radiograph

Fig. 15: Intermediary cephalometric profile radiograph

Post-treatment cephalometric evaluation (Fig 16) confirmed the improvement of anteroposterior discrepancy of maxilla (SNA from 89º to 85º), and it was observed the maintenance of mandible position (SNB 80º). Furthermore, ANB presented an improvement (from 9º to 5º), indicating a skeletal Class II that is in a lower gravity. Maxillary and mandibular incisors remained in a good position.

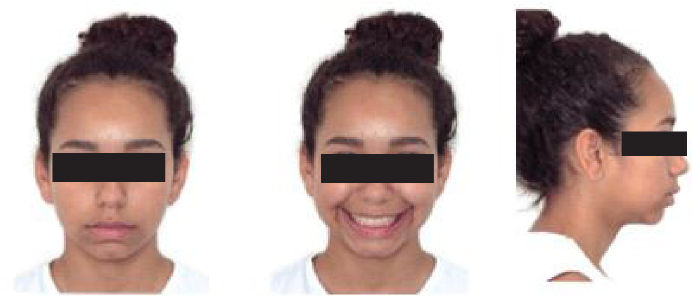

Fig. 16: Final extraoral photographs

Fig. 17:Final intraoral photographs

Fig. 18: Final panoramic radiograph after treatment

Fig. 19: Final cephalometric profile radiograph

Discussion

Impaction of incisors, canines, premolars, and second molars are frequently present in clinical practice.[11] After the third molars, the maxillary canines are the teeth that suffer the most impaction and may have a multifactorial etiology.[11] One of the etiological factors related to impaction that is usually mentioned in the literature is trauma.[8] In the present case, the patient had suffered a dental trauma that possibly caused teeth 21 and 23 impactions, which was diagnosed after clinical examination and image exams.

In addition to the clinical examination, image exams should be requested to help in the diagnosis, such as radiographs and computed tomography,[12] an approach that was performed in the present case. The computed tomography images are important to execute teeth tractions, allowing the orthodontist to precisely identify the position of impacted teeth, evaluate possible injuries to adjacent roots, helping detect the existence of ankylosis of teeth.[12] After the orthodontic traction, side effects such as ankylosis[13] and external root resorption of the tractioned tooth or adjacent teeth can be observed.[14] An ideal treatment plan in impacted teeth cases mostly contains a multidisciplinary team, including pediatric dentistry, orthodontics, and surgery. These professionals should be able to identify early eruption difficulties, decide the ideal orthodontic mechanics that will be applied in the treatment, and choose the surgical procedure, when necessary.[14]

Orthodontic traction of the impacted canine is more indicated in cases with greater chances of a better prognosis, as occurs with patients who are growing and without severe deficiencies of arch space.[14] The most common procedure performed to allow impacted canines' traction is their surgical exposure when it is placed a bonded attachment in an overexposed area, followed by the orthodontic traction.[15] The surgical exposure of impacted maxillary canines can cause dental ankylosis.[13] To prevent ankylosis after orthodontic traction, the rapid maxillary expansion is suggested as a treatment method for impacted maxillary canines in young patients.[16]

As it has been described in the literature, it is necessary to create space in the arch prior to orthodontic movement.[17] In the treatment of malocclusion involving impacted canines, the space creation can be achieved by a palatal expander appliance or premolar extraction.[17] In the present clinical case, the first orthodontic treatment was rapid maxillary expansion using a Hyrax rapid palatal expander for space acquirement, which presented a welded handle next to the palatal region of tooth.[11] A slight traction of tooth 22 was started using that handle as anchorage, followed by surgical exposure and another traction, which was performed by a horizontal vector, promoting the movement of 23 to the buccal region, followed by its distal movement. Rapid maxillary expansion can lead to spontaneous eruption of the impacted tooth.18 That result was found in the present report, whereas three weeks after the expander was installed, tooth 21, which was impacted, began to erupt.

The knowledge of orthodontic mechanics is essential in cases of traction of impacted canines since the correct management of applied forces can prevent further injuries to adjacent teeth.[19] In the present clinical case, the post-treatment radiographic image evaluation did not show signs of external root resorption of either the tractioned tooth or adjacent teeth, despite some studies shows that this is the main side effect related to orthodontic traction of impacted teeth.[14] Besides, in the post-treatment radiographic image evaluation showed that tooth 21 had a root dilaceration, which was also shown in the initial radiography, possible due to the trauma suffered in that region.

The case reported in this article involves a growing patient, which allowed the use of interceptive orthodontics. Proper management of impacted canines from a functional and aesthetic point of view is important for the success of orthodontic therapy.[12] Among the various treatment options, the orthodontist must choose the one that best meets the patient's needs and interests.[13] The most suitable method to be chosen should be the one that allows the application of ideal traction forces in the most favorable direction, avoiding further damage to adjacent teeth.[14]

Conclusion

Despite the results achieved, the difficulties inherent in the challenges of treatments involving traction, as well as patient's personal limitations, such as intolerance to continue treatment after her main complaint was resolved, were factors associated with the long duration of treatment, composing its efficiency. Even considering the prolonged duration of treatment, there was a significant improvement in patient's quality of life and in her smile aesthetics and functions. Therefore, the planning and intervention of malocclusion cases in the primary and/or mixed dentition phase should be considered whenever indicated, tailored to individual growth patterns.

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FEATURED*

Analysis of Vertical Facial-Growth Patterns

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Abstract:

Objective: This study aimed to identify similarities and differences in vertical facial growth patterns between five patients undergoing orthodontic treatment and review the relevant literature to contribute to a deeper understanding of potential clinical implications and orthodontic treatment approaches for patients with Class III malocclusion and vertical facial growth. Additionally, we discuss an effective approach to determine the environmental factors that lead to vertical growth and ways to combat these factors

Keywords: Malocclusion; Appliances; mouth breathing; Occlusion; Open Bite; Vertical Growth; Class III Malocclusion; Breast feeding; Nonnutritive sucking; Thumb Sucking; Tongue Thrusting; Tongue Positioning

Conflict of Interest: None

Introduction

Vertical facial growth refers to developmental changes in the vertical dimensions of the face and jaw. This process significantly influences the facial aesthetics, occlusion, and overall oral health. Excessive vertical growth can occur in either or both the jaws, influences tooth alignment and positioning, and plays a crucial role in determining facial proportions. The potential effects of vertical facial excess include alterations in airway function and susceptibility to temporomandibular joint and systemic-health problems. Understanding the dynamics of vertical facial growth is vital for orthodontists to tailor effective treatment plans to achieve aesthetically pleasing smiles and optimal airway harmony.

Malocclusion is a common dental problem that can cause several oral problems such as decayed teeth, masticatory problems, and gum disease. Patients with Class III malocclusion require immediate attention and appliances to gently pull the teeth into alignment and prevent a permanent underbite. If the problem is left untreated, adolescents may experience symptoms ranging from mild migraines and trouble chewing to more serious mandibular discrepancies requiring surgery. To avoid such complications, parents should prioritize their children's oral health and take appropriate precautionary steps at an early age to ensure proper jaw formation. Orthodontic treatment using fixed and/or removable appliances is important for preventing skeletal open bites and correcting malocclusion.

Although hereditary factors influence vertical skeletal growth, minimizing the risk and rate of vertical growth by reducing the influence of environmental factors is important. Skeletal open bites are genetic abnormalities shaped by environmental conditions. The most common environmental contributors to vertical growth in pediatric patients include thumb and finger sucking, mouth breathing, and tongue thrusting.[1] Nasal congestion, allergies, and other obstructions to the nasal airway hinder the patient's ability to swallow, leading to tongue thrusting and mouth breathing.

This study aimed to explore the factors that influence Class III malocclusion and vertical facial growth. In addition, we explored potential solutions, such as early age interventions, while addressing the financial implications of these proposed measures.

Results

Assessment of the sagittal profiles of five patients (Figures 1-5) with Class III malocclusion revealed notable physical similarities such as a long face, droopy eyes, high-arched eyebrows, and a distinctive jaw shape accentuated by vertical growth. The dental features included a posterior crossbite, anterior open bite, narrow maxillary arch, and retruded maxilla, leading to a constricted nasal passageway that contributed to mouth breathing. All five patients experienced daytime sleepiness, nasal obstruction, forward head posture and

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neck discomfort. Addressing this condition involves orthodontic treatment, including corrective appliances, such as Hawley appliances, fixed appliances, functional appliances, chin cups, protraction face masks, and bone-anchored appliances.[2] However, appliance-based treatment options are expensive and time-consuming. Therefore, orthognathic surgery may be required depending on the severity and needs of the individual. Although surgical treatment offers immediate results, it is associated with complications such as cranial-nerve injury and disruption.[3]

Fig. 1: Patient 1, (L to R and bottom) sagittal view, maxillary arch occlusal view, and anterior open bite

Fig. 2: Patient 2. (L to R) Sagittal view, maxillary arch occlusal view, and anterior open bite

Fig 3. Patient 3. (L to R): Sagittal view,maxillary arch occlusal view and anterior open bite. This patient had previously undergone orthodontic treatment with a maxillary expander for two years.

Fig. 4. Patient 4. (L to R) Sagittal view,maxillary arch occlusal view, and anterior open bite

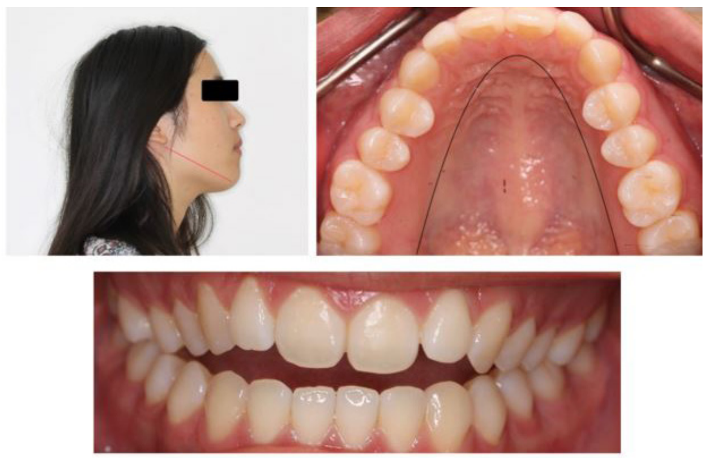

Fig. 5: Patient 5. (L to R) Sagittal view, anterior open bite,and maxillary arch occlusal view

All patient photos used with signed consent

Discussion

Class III malocclusion may occur due to mandibular prognathism, and excessive vertical growth of the lower jaw compared with that of the upper jaw. An overdeveloped mandible results in an underbite, where the lower incisors are positioned anterior to the upper incisors and can affect the position and size of the nasal cavity. Malocclusion compromises the tooth position and natural pattern of mandibular skeletal growth, leading to upper-airway obstruction. Therefore, individuals with Class III malocclusion may experience nasal obstruction or difficulty in breathing through the nose, especially if the retruded maxilla encroaches on the nasal space. Furthermore, patients with an increased mandibular plane angle, an extended lower or upper jaw, and uneven open bites exhibit a dominant tendency to rely on mouth breathing instead of nasal breathing. While forward head posture is sometimes noted in these patients, its occurrence is more closely tied to condylar position than to the Class III classification itself. In most Class III cases involving a retrognathic maxilla, the condyle tends to be positioned distally, which may influence head posture; however, functional Class III malocclusions do not always show forward head tilt and may, in certain cases, present with the opposite pattern.[11] Patients who rely on mouth breathing exhibit similar craniofacial growth patterns including contraction of the maxillary dental arch, excessive gum display, or mandibular prognathism, which contribute to the "long face" appearance and are characteristic of skeletal class III malocclusion.

Thumb sucking may lead to malocclusion because pressure is exerted on the developing teeth and jaw. This pressure causes the maxillary incisors to tip outward and the mandibular incisors to tip inward, resulting in malocclusion. A previous study[4] revealed that the breastfeeding duration plays a crucial role in the development of sucking habits. Infants breastfed for <6 months are likely to have a higher dependency on pacifiers. This seemingly harmless habit can be detrimental to a child's jaw alignment and occlusion, because it leads to future non-nutritive sucking, such as thumb and finger sucking.

Mouth breathing alters the resting tongue posture, shifting it from the natural position against the roof of the mouth to a lower resting position. This change can contribute to the narrowing of the upper jaw and an uneven bite. Furthermore, a narrow jaw affects development of the dentition, leading to crowded or crooked teeth. Additionally, mouth breathing results in dry mouth. Without sufficient saliva, the growth of harmful bacteria cannot be prevented, and teeth are more prone to caries. In addition to poor dental hygiene, chronic mouth breathers struggle with simple tasks such as biting and chewing. Malocclusion affects the performance of these daily tasks because the upper and lower teeth do not meet properly. Therefore, early detection and management of mouth breathing are crucial for preventing skeletal malocclusion.[5]

Abnormal tongue size and posture can influence vertical facial growth by affecting the balance of forces within the oral cavity. An oversized tongue or incorrect tongue posture may lead to improper oral muscle function and exert abnormal pressure on the teeth and jaws. This imbalance can contribute to issues such as open bite and excessive vertical growth of the face and jaws. Orthodontic treatment aims to correct these imbalances and often involves interventions to improve tongue posture and address the associated growth abnormalities. Poor resting tongue posture and tongue thrusting can contribute to bite problems and mouth breathing.6 This is because the tongue exerts pressure on the teeth and can displace them over time. Tongue thrusting occurs when the tongue presses forward or too far from the sides, usually during swallowing.

Non-nutritive sucking is a habit formed in young children and babies that can be detrimental to oral development. Notably, non-nutritive sucking, such as thumb or pacifier sucking, correlates with future dental problems, such as deviated dental midlines, disturbed overlapping of incisors, and vertical growth of the lower jaw.[7] Persistent thumb sucking exerts pressure on a child's developing teeth and jaws, resulting in malocclusion. A study on nonnutritive sucking found that an early transition from breastfeeding to pacifier sucking led to a heavier reliance on nonnutritive sucking. Children breastfed for <6 months were four times more likely to develop a high reliance on pacifier sucking. Furthermore, the prevalence of non-mesial-step occlusion was higher in children who were bottle fed for >18 months.[4] While seemingly harmless, a prolonged habit of digit sucking was found to affect occlusion, often leading to the development of an anterior open bite, excessive overjet, or the absence of a lower jet development space. To minimize the risk of malocclusion, parents should focus on their children's early weaning and non-nutritive sucking habits. Breastfeeding is a necessary process that should last for at least 6 months to promote healthy development in growing children. Once a child transitions to bottle feeding and pacifier sucking, it is important for the parent to supervise non-nutritive sucking and limit its span to a maximum of 18 months.

Mouth breathing is another common habit associated with poor facial development and decreased quality of life. Chronic mouth breathing develops during childhood and is prevalent in 10-25% of all children. The majority of mouth breathing is a result of nasal obstruction or jaw misalignment that can be resolved through allergy medication, orthodontic appliances, or surgical treatment in extreme cases. In the BMC Oral Health systematic review looking into the effects of mouth breathing, the impact of mouth breathing significantly influenced the underdevelopment of the jaw, with both the mandible and maxilla showing a tendency to rotate backward and create an overbite in chronic mouth breathers. Mouth-breathers showed increased angles in the mandibular, palatal, and occlusal planes, potentially affecting the temporomandibular joint.[10] The ascending ramus of the lower jaw is also underdeveloped in mouth-breathing children because the upper anterior teeth tend to incline labially, while the lower anterior teeth do not. This causes a narrowed airway leading to compensatory jaw growth in children with airway obstruction. Orthodontists must focus on encouraging normal mandibular growth in children with mouth breathing habits to prevent adverse craniofacial development. Orthodontic appliances to guide jaw growth is crucial for proper midface development that will help open the patient's airway. Early detection of vertical growth is important for successful jaw and teeth alignment through orthodontic treatment rather than orthognathic surgery.

To preempt surgical treatment, we propose an alternative approach for identifying developing Class III malocclusions and initiating early preventative measures before significant vertical facial growth. Elementary-school nurses , with their accessibility to young growing children, could play a pivotal role in the early identification of the problem by assessing signs of vertical facial growth such as a narrow maxillary arch, mouth breathing, and tongue thrusting. Mouth breathing in children leads to altered craniofacial development, such as vertical facial growth. Nurses can perform basic breathing tests, such as a mouth/lip seal test, water retention test, and fog test using a mirror, to identify dominant mouth breathing.[8] Questions should also be directed at the child or parent/guardian to determine potential allergies and to assess breathing and sleeping habits. Parents can arguably play the greatest role in preventing future vertical facial growth and identifying mouth breathing by paying close attention to their children's breathing habits, allergies, sleeping patterns, and facial features. Parents should aim to answer questions such as "Does my child leave their mouth open when distracted?" "Do they snore or drool during sleep?" "Do they suffer from a constant stuffy nose and/or allergies?" "Are they experiencing difficulty concentrating?"[8] Answering these questions can help parents diagnose mouth breathing in their children and seek orthodontic care before malocclusion occurs. Alternatively, parents may proactively arrange routine checkups with their family or pediatric dentists to prevent malocclusion in their children.

With these simple tests, nurses can help the child and parents identify developing malocclusion and harmful breathing patterns and refer them to an oral specialist such as a pediatric dentist, orthodontist, or general dentist before they require extensive corrective treatment. Dentists possess the expertise to identify early signs of vertical facial growth, allowing for timely intervention and averting the need for costly treatments. Early diagnosis and treatment can prove financially prudent, minimizing expenses compared with those for corrective dental treatment later in life. Our findings suggest that characteristics such as narrow nasal passageways, a unique jaw morphology, and specific facial features are common in all patients included in this study. Furthermore, they underscore the multifactorial etiology of vertical facial growth and Class III malocclusion, including issues such as mouth breathing, non-nutritive sucking, and tongue thrusting.

Our proactive approach involving breathing exercises and monitoring the tongue position not only averts complex treatments in the future, but also proves to be a cost-effective and risk-minimizing solution in terms of oral health and financial savings.

Recommendations:

Early detection of vertical facial growth indicators—by school nurses, parents, and oral health specialists—remains essential in preventing the progression of malocclusion. Proactive intervention strategies aimed at eliminating harmful oral habits can significantly reduce the risk of adverse craniofacial development. Incorporating advanced imaging techniques, such as cephalometric analysis or CBCT scans, can further enhance diagnostic accuracy by providing detailed insights into condylar position and skeletal relationships. This information is critical for developing dependable treatment plans that minimize relapse potential.

This study was based on data from a small number of patients within a single practice. To strengthen the evidence and broaden the applicability of these findings, future research should involve larger sample sizes and include patients from multiple clinical settings and geographic locations.

Conclusion

This study highlights several shared characteristics among the patients observed, including narrow nasal passageways, distinctive jaw morphology, and specific facial features often associated with vertical facial growth. Our findings reaffirm the multifactorial nature of Class III malocclusion—shaped not only by genetic factors but also by environmental influences such as mouth breathing, non-nutritive sucking, and tongue thrusting. In addition, the role of condylar position in influencing posture and skeletal relationships underscores the importance of comprehensive assessment.

Early, targeted interventions—ranging from habit correction to breathing exercises and tongue-posture training—offer the potential to prevent more complex treatment needs later in life. When paired with advanced imaging tools like cephalometric analysis or CBCT, clinicians can gain a clearer understanding of skeletal and joint dynamics, enabling treatment plans that are both dependable and less prone to relapse. Such a proactive, informed approach is not only clinically effective but also cost-efficient, ultimately improving long-term oral health outcomes.

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Myofunctional vs. Fixed Functional: A Comparative Study in Changes in Airway Dimension and Hyoid Bone Position

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Abstract

Aim and Objectives: To evaluate the change in pharyngeal airway dimension and hyoid bone position following treatment with removable functional appliance in cases with mandibular retrognathism.

Material and Methods: Pre and post functional lateral cephalometric radiographs of 25 growing Class II patients (13 males and 11 females) in the age range of 8 to 14 years treated with myofunctional appliance were compared with a control sample of 20 Class II subjects (11 males and 10 females) in the age range of 8 to 15 years. For control group, Class II growing individuals were chosen who have not undergone any sagittal correction because of various reasons such as excessive lower incisor proclination or lack of patient compliance, etc. Lateral cephalograms were recorded at the beginning (t0) and end of 9 months (t1) for both groups.

Results: After functional treatment, the dimension of oropharynx and hypopharynx increased significantly compared to the control group. There was an increase in PPS from 22.08±1.44 mm to 22.56±1.73 mm, but the change was not statistically significant (p=0.29). The SPPS, MPS, IPS increased significantly in the functional group, i.e. p=0.0029, 0.0001, 0.0008, respectively. HRGN measurement showed statistically significant decrease (p=0.04) in dimension, suggesting the hyoid bone moved forward after functional therapy. The vertical position of the hyoid bone in the post-functional group showed no significant difference from the control, indicating that growth development plays a vital role in vertical control of the hyoid bone.

Conclusion: Oropharynx and hypopharynx increased significantly after functional therapy as compared to control. A weak but positive correlation was found between increase in airway dimension and forward movement of the hyoid bone. Sexual dimorphism was not present for change in pharyngeal airway dimension and hyoid bone position in this study.

Keywords: Hyoid, Myofunctional, Fixed Functional

Conflict of Interest: None

Introduction

Class II malocclusion represents the most common skeletal discrepancy which an orthodontist encounters in daily practice. Skeletal Class II pattern more commonly is associated with increased overjet and overbite, retrusion of the mandible, and a short length of the ramus. Battagel et al.[1] reported a more posterior position of the hyoid bone in Class II subjects with a narrower upper airway. Severe mandibular deficiency in Class II has been linked to reduced oropharyngeal airway (OAW) dimensions.[2]

Decreased space between the cervical column and the mandibular corpus may lead to a posteriorly postured tongue and soft palate, leading to narrowing of the pharyngeal airway and increasing the chances of impaired respiratory function during the day and possibly causing nocturnal problems as well, such as snoring, upper airway resistance syndrome (UARS), and obstructive sleep apnea syndrome (OSAS).[3]

In general consideration of the cervicofacial skeleton, the hyoid bone tends to be overlooked, or is given scant attention. It is associated with several important functions of the human body such as deglutition, phonation, and respiration. It forms the anterior body of the airway. Hence, any change in its position can adversely affect the dimensions of the airway.[4] Functional appliance therapy corrects the malocclusion in actively growing children by redirecting the maxilla-mandibular growth in a more forward direction so that a better facial profile is developed. As the posture of the mandible is manipulated anteriorly during treatment, it is postulated that there is a concomitant improvement in the posterior airway space.[5,6] Ozbek et al.[7] reported increase in the oropharyngeal airway dimensions following functional-orthopedic treatment in skeletal Class II cases. Ghodke et al.8 reported that correction of mandibular retrusion by twin-block appliance in Class

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II malocclusion subjects increased the posterior airway passage dimensions and maintained the pre-treatment thickness of posterior pharyngeal wall.

However, there is a lack of studies which have evaluated change in the hyoid position and the pharyngeal airway dimensions following treatment with functional appliance and even more rare is correlation between them.[9]

As far back as 1986, Riley et al.[10] demonstrated a correlation between assessments based on CT scans and assessments based on cephalograms, which led them to conclude that the latter was appropriate for basic diagnostic purposes.

This study was planned to evaluate the changes in hyoid bone position and their correlation with pharyngeal airway space after treatment with myofunctional appliance in cases with mandibular retrognathism.

Material and Method

Forty-five (M = 24, F = 21) growing subjects in the age range of 8 to 15 years with skeletal Class II malocclusion associated with mandibular retrusion were selected for this retrospective study. Study sample calculation was performed based on a formula previously described by Pandis.[11] A sample size of at least 18 patients in each group would be necessary to detect a mean difference of 2.12 ± 0.67 mm for the pharyngeal dimension with a test power of 90% (p = .05 significance level). Therefore, 18 individuals in the control group and 25 individuals in the treatment group were taken.

The radiographs collected were exposed with the patient seated in an upright position with Frankfort horizontal plane parallel to the floor. Patients were instructed to breathe at ease with the teeth in centric occlusion. The radiographs were obtained with KODAC 8000 C Digital Panoramic and Cephalometric system with an output of 70 KV, 10 Ma. All cephalograms were recorded with same exposure parameters.

Inclusion Criteria:

1. Angle Class II molar relationship
2. ANB ≥ 4 degrees
3. SNB ≤ 78 degrees depicting mandibular retrognathism
4. FMA in the range of 20° to 25°
5. Overjet > 5mm
6. Significant growth potential at the beginning of the treatment period as analyzed with hand wrist radiographs

Exclusion Critera:

1. Any known respiratory problem
2. Any naso-oropharyngeal obstruction
3. Patients who have undergone surgical upper airway operations before or during the treatment
4. Class II Div 2 cases with backward path of closure were excluded from the control group.

Method of Assessment:

Pre and post functional lateral cephalometric radiographs of 25 growing Class II patients (13 males and 11 females) with the mean age of 11.18±2.8 years treated with myofunctional appliance were compared with a control sample of 20 Class II subjects (11 males and 10 females) with the mean age of 11.86±3.2 years.

As the patients involved in our research were young, their normal development may affect the upper airway morphology during the treatment period. Thus, an untreated control group was needed. For ethical reasons, no untreated control group was available. Therefore, Class II growing individuals were chosen who have not undergone any sagittal correction because of various reasons such as excessive lower incisor proclination or lack of patient compliance, etc.

Lateral cephalograms were recorded at the beginning (t0) and at the end of the observation period of 9 months (t1) for the control group. In the treatment group, individuals were treated by removable functional appliance with both pre (t0) and post (t1) functional records. Post functional records were taken after the patient has attained a pleasing profile (approximately 9 months). Landmarks and measurements used in the study were:

Cephalometric Landmarks (Figure 1:)

- S: sella
- N: nasion
- CV2tg: the tangent point of the superior, posterior extremity of the odontoid process of the second cervical vertebra
- CV2ip: the most infero-posterior point on the body of the second cervical vertebra
- CV4ip: the most infero-posterior point on the body of the fourth cervical vertebra
- P: tip of soft palate
- SP: midpoint of soft palate
- PNS: posterior nasal spine
- Me: menton
- Go: gonion
- B: point B
- RGN: retrognathion
- H: hyoid
- C3: Anteroinferior limit of third cervical vertebra.
- Go-Me: Mandibular plane
- Go-B line: Reference line

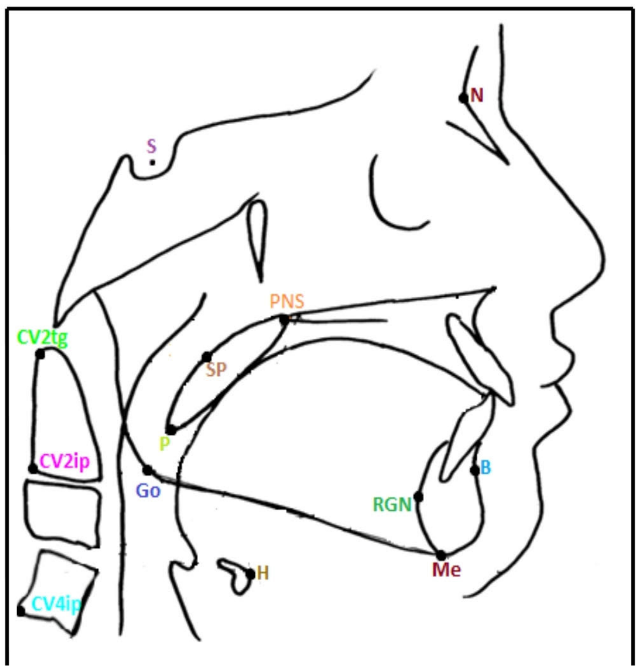

Figure 1: Cephalometric landmarks

Cephalometric Measurements (Figure 2):

Pharyngeal airway space analysis:-

1. PPS, palatal pharyngeal space (from PNS to upper pharyngeal wall along parallel line to Go-B line)
2. SPPS, superior posterior pharyngeal space (from midpoint of soft palate to posterior pharyngeal wall along parallel line to Go-B line)
3. MPS, middle pharyngeal space (from tip of soft palate to posterior pharyngeal wall along parallel line to Go-B line)
4. IPS, inferior pharyngeal space (width of airway space along Go-B line) Hyoid bone analysis:-Vertical measurement
5. MPH, perpendicular distance from hyoid bone to mandibular plane
6. HH1, perpendicular distance from hyoid bone to the line connecting C3 and RGN Antero-posterior measurement
7. HRGN, distance between hyoid bone and RGN
8. C3H, distance between hyoid bone and C3

Craniocervical inclination:

9. SN-CVT, the downward angle between the SN plane and the line through Cv2tg and Cv4ip
10. SN-OPT, the downward angle between the SN plane and the line through Cv2tg and Cv2ip.

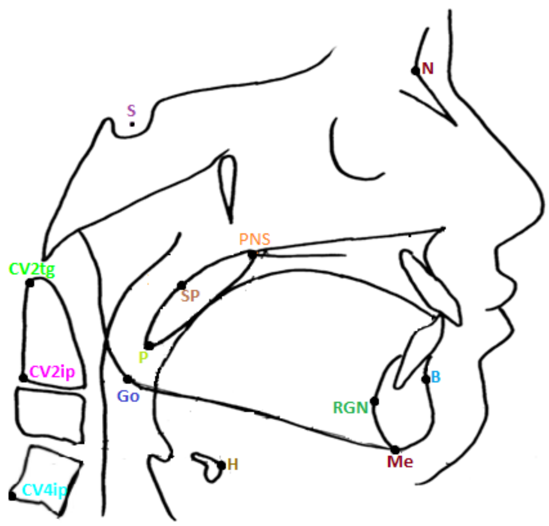

Figure 2. Cephalometric measurements

ERROR OF METHOD:

To determine the errors associated with radiographic measurements, 10 cephalograms were selected at random. Their tracings and measurements were repeated four weeks after the first measurements, and the random method was assessed. The mean difference between the first and second measurements, the standard error of a single measurement, and the percentage of total variance attributable to measurement errors were calculated for each measurement. The casual error according to Houston`s formula ($ME = \sqrt{\sum d^2/2n}$) and the systematic error with dependent t tests at $p<0.05$ were calculated.

STATISTICAL ANALYSIS:

Statistical procedures were performed on the recorded data using manual cephalometric tracing method. The collected data, as a whole, were statistically analyzed by descriptive analysis for mean, range, and standard deviation using SPSS software (SPSS for Windows, Release 7.5.1, Chicago, USA). The differences between males and females were tested using parametric Student's t-test. The significant changes within the group (pre and post-treatment/post-follow-up values) were determined by nonparametric paired t-test, and the mean differences among the groups were compared by Student t- test. The p value of 0.05 was considered as the level of significance.

Pearson product moment correlation coefficients were sought between changes in airway dimensions and hyoid movement after functional therapy.

RESULTS

The demographic data of the sample showed that the mean age of the males and females was 11.90 ± 1.48 years and 10.94 ± 1.86 years, respectively.

Table 1 and Figure 3 showed the mean difference between males and females of the changes attained after functional therapy in myofunctional group. No statistically significant difference was found between males and females for any of the variables. Hence, the two groups were further statistically analyzed as one to increase the power of the study.

Table 1: Gender dimorphism in myofunctional group

Mean difference (myofunctional)	Male Mean±S.D	Female Mean±S.D	t test	CI (95%)	p value
PPS	0.09±0.74	0.09±0.02	5.146	0.6123- 1.2077	0.6
SPPS	2.69±0.98	2.62±0.89	4.04	0.5377- 1.6023	0.5
MPS	4.31±1.36	4.41±1.02	5.588	1.2164- 2.5836	0.3
IPS	3.81±1.12	3.17±0.78	4.671	2.0912- 3.1888	0.32
MPH	2.42±0.87	2.59±0.93	4.594	-1.6821--0.6579	0.1
HH1	0.77±0.47	1.50±0.81	3.898	-1.1066--0.3534	0.6
HRGN	-3.61±1.07	-3.59±0.96	3.548	0.4419- 1.5981	0.5
C3H	1.46±0.84	0.96±0.74	5.690	1.1222- 1.7978	0.9

($p<0.05$ Significant, $p<0.001$ Highly Significant)

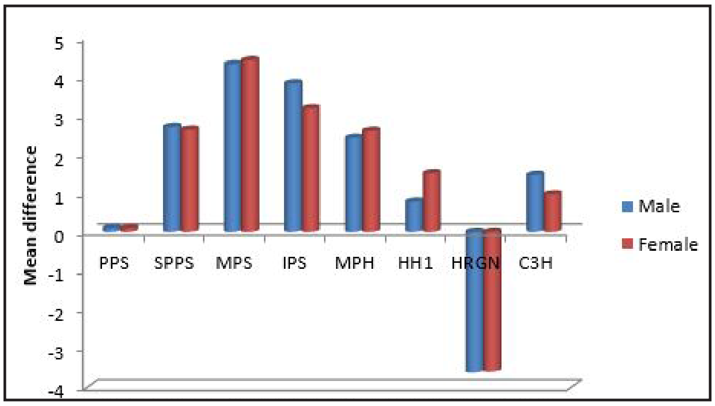

Figure 3. Gender Dimorphism in Myofunctional Group

Table 2 and Figure 4 showed no statistically significant difference between males and females of the changes attained on observation in the control group. Hence, the two groups were further statistically analyzed as one to increase the power of the study.

Table 2: Gender dimorphism in control group

Mean difference (control)	Male Mean±S.D	Female Mean±S.D	t test	CI (95%)	p value
PPS	0.73±0.32	0.37±0.18	4.160	0.1841- 0.5359	0.2
SPPS	0.35±0.15	0.25±0.11	2.281	0.0109- 0.1891	0.3
MPS	1.20±0.58	1.19±0.10	7.2806	0.7281- 1.2919	0.1
IPS	0.45±0.21	0.63±0.27	2.232	-0.3438--0.0162	0.3
MPH	0.9±0.36	0.88±0.29	0.1836	-0.2014- 0.2414	0.85
HH1	1.25±0.70	1.68±0.79	2.8427	-0.9089--0.1511	0.75
HRGN	0.90±0.31	0.87±0.26	0.3146	-0.1638- 0.2238	0.55
C3H	0.82±0.49	1.26±1.24	4.741	-1.0858--0.4342	0.5

(p<0.05 Significant, p<0.001 Highly Significant)

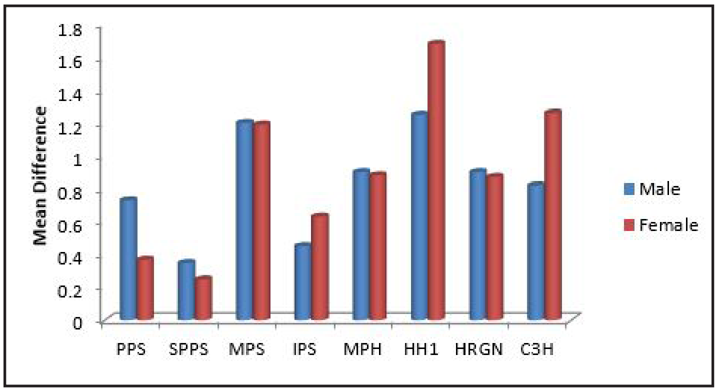

Figure 4. Gender Dimorphism in Control Group

Table 3 and Figure 5 showed the airway dimension and hyoid bone changes in the treatment group. There was an increase in PPS from 22.08±1.44 mm to 22.56±1.73 mm, but the change was not statistically significant (p=0.29). The SPPS, MPS, IPS measurements showed statistically significant increase in airway dimensions between the pre treatment and post treatment groups, i.e. p=0.0029, 0.0001, and 0.0008 respectively. Among the hyoid bone variables, only the HRGN measurement showed statistically significant decrease (p=0.04) in dimension. Craniocervical angulation (SNCVT and SNOPT) was comparable at the beginning of t0 and t1 period.

Table 4 and Figure 6 showed no significant change in the airway dimension and hyoid bone position in the control group.

Table 5 and Figure 7 showed the mean difference between the changes attained after functional therapy in myofunctional group compared to the control group. Among airway variables, PPS showed least significant difference (p=0.002) and SPPS, MPS, IPS highly significant (<0.0001). MPH, HH1, and HRGN showed statistically significant difference among myofunctional and the control group i.e. p = 0.0024, 0.0049, <0.0001 respectively and no significant difference was seen in C3H value, i.e. p = 0.5151 between both the groups. Also changes in craniocervical angulation during treatment and observation periods were not

Table 3: Pre and Post functional Means, Related Standard Deviations, t value, confidence interval and p Values of myofunctional group

Myo Functional	Pre Mean±S.D	Post Mean±S.D	t test	CI (95%)	p value
PPS	22.08±1.44	22.56±1.73	1.0662	-1.3851-0.4251	0.2916
SPPS	11.32±2.27	13.48±2.49	3.2053	-3.5149--0.8051	0.0024
MPS	9.68±2.17	13.12±2.91	4.7383	-4.8997--1.9803	0.0001
IPS	9.96±2.51	12.96±3.34	3.5902	-4.6801--1.3199	0.0008
MPH	12.32±4.62	12.80±4.34	0.3786	-3.0290-2.0690	0.7066
HH1	8.88±6.84	10.04±6.21	0.6278	-4.8750-2.5550	0.5331
HRGN	38.32±4.96	35.20±5.93	2.0179	0.0112-6.2288	0.049
C3H	33.36±4.26	34.12±3.89	0.6587	-3.0798-1.5598	0.5132
SN/CVT	104.54±5.8	105.36±4.7	0.3389	-3.0246-2.4842	0.7829
SN/OPT	102.84±3.6	103.24±4.8	0.3125	-2.6231-2.1964	0.7234

(p<0.05 Significant, p<0.001 Highly Significant)

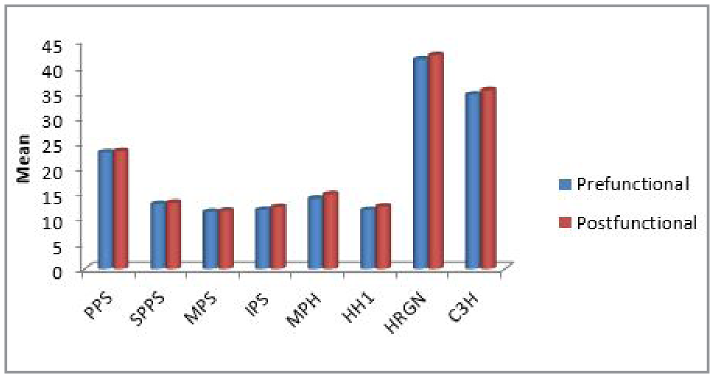

Figure 5: Pre and Post Functional Means

Table 4: Pre and Post functional Means, Related Standard Deviations, t value, confidence interval and p Values of myofunctional group

Control	Pre Mean±S.D	Post Mean±S.D	t test	CI	p value
PPS	23±2.66	23.22±2.84	0.2354	-2.1191-1.6791	0.8153
SPPS	12.78±2.80	13.06±2.82	0.2989	-2.1835-1.6235	0.7668
MPS	11.22±3.66	11.39±3.90	0.1349	-2.7319-2.3919	0.8935
IPS	11.61±3.63	12.17±4.26	0.4245	-3.2409-2.1209	0.6739
MPH	13.83±6.06	14.72±5.93	0.6589	-4.9513-3.1713	0.4453
HH1	11.56±7.71	12.28±7.61	0.2820	-5.9091-4.4691	0.7797
HRGN	41.28±7.19	42.17±7.66	0.3594	-5.9223-4.1423	0.7215
C3H	34.39±3.68	35.22±3.87	0.6594	-3.3880-1.7280	0.5141
SN/CVT	104.62±4.8	105.16±6.4	0.3654	-3.4928-2.4643	0.7246
SN/OPT	102.82±4.2	103.52±4.6	0.3298	-2.2459-2.2514	0.7164

(p<0.05 Significant, p<0.001 Highly Significant)

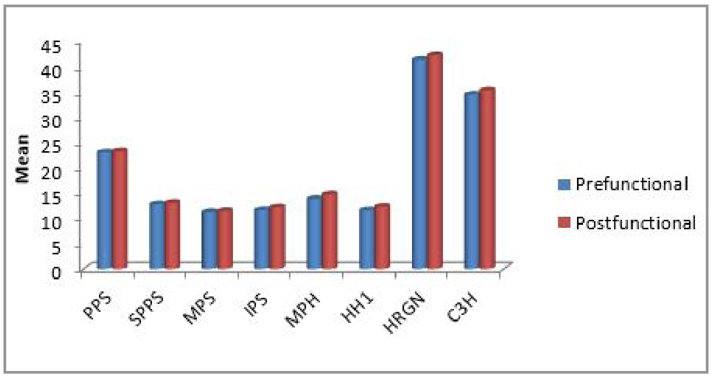

Figure 7: Pre and Post Functional Means

Table 5: Mean difference, t value and p value of control Vs myofunctional

Mean difference	Myo Functional (Mean difference)	Control (Mean difference)	t test	CI	p value
PPS	0.48±0.16	0.32±0.10	5.0809	0.1737-0.3463	0.0018
SPPS	2.16±0.96	0.28±0.11	8.242	1.4193 - 2.3407	<0.0001
MPS	3.44±1.24	0.17±0.08	11.1338	2.6769-3.8631	<0.0001
IPS	3.00±1.09	0.56±0.19	9.3648	1.9138-2.9662	<0.0001
MPH	0.48±0.14	0.89±0.47	3.431	-0.6104--0.2096	0.0024
HH1	1.16±0.58	0.72±0.28	2.9717	0.1410-0.7390	0.0049
HRGN	3.12±1.13	0.89±0.45	7.9117	1.6608-2.7992	<0.0001
C3H	0.76±0.29	0.83±0.41	0.6566	-0.2853-0.1453	0.5151
SN/CVT	0.81±0.82	0.53±0.72	0.5846	0.5246-0.8842	0.5629
SN/OPT	0.39±0.64	0.70±0.84	0.6095	0.6231-1.0255	0.5234

(p<0.05 Significant, p<0.001 Highly Significant)

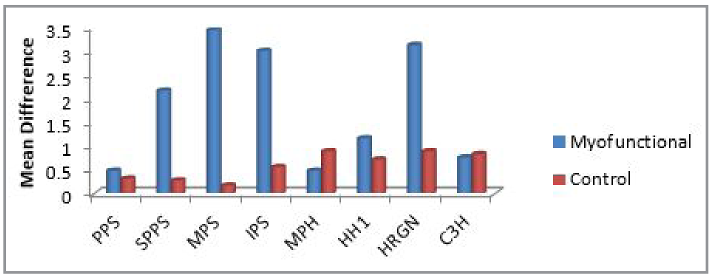

Figure 6: Pre and Post Functional Means

Myofunctional	MPH	HH1	HRGN	C3H
PPS	0.5994	0.0543	-0.1987	0.1209
SPPS	0.0629	0.4523	-0.0318	0.0343
MPS	0.2136	0.4521	-0.0351	0.0557
IPS	0.0967	0.3577	-0.0424	0.1146

Table 6: Correlation between airway parameters and hyoid bone parameters

found to be significant.

Table 6 showed the correlation between the changes attained in pharyngeal airway dimensions after functional therapy and the changes attained in hyoid bone position after functional therapy. There is a weak but positive correlation between the change in PPS, SPPS, MPS, IPS, and change in C3H, and all these variables are negatively correlated with change in HRGN.

Discussion

Lateral cephalometry is an established tool in the investigation of the airway, and it has been employed for diagnostic purposes and to monitor therapeutic response.[1] Reproducibility of airway dimensions on lateral cephalograms has been studied and found to be highly accurate.[12]

A relationship between the head position (such as head extension/ flexion or upright/ supine positions) and upper airway dimensions has been proposed by many investigators.[13,14] Therefore, to avoid misinterpretations, headfilms should be taken in a natural head posture (NHP). Unfortunately, this could not be accomplished due to the retrospective design of this study; all x-rays had been taken using conventional methods, that is, Frankfurt horizontal parallel to the floor. Therefore, measurements of craniocervical angulation were calculated to test if there were any significant differences between groups at the beginning and of changes within the groups after the functional and observation period. As differences were not found to be significant, it was proposed that the results were not significantly affected by differences of head posture.

Gender dimorphism

Comparing the changes between genders, there were no significant differences in the hyoid bone position or airway parameters in either group during the period t0 – t1. This is in accordance with the study by Hanggi et al[15] who in their longitudinal study after activator headgear treatment found that at the long-term follow-up, the absolute values for females were similar to those of the males for pharyngeal airway dimension and hyoid bone position. Therefore, it was determined that the sexual dimorphism was not present for the two groups in this study.

Pharyngeal airway

Small airway dimension and anatomical adaptation of the soft palate are common features in subjects with retrognathic mandible. Previous literatures reported obvious dimensional changes in the oropharynx following mandibular advancement treatment, suggesting that the patency of the oropharynx was attributed to a forward repositioning of the tongue and soft palate with the mandibular advancement.[7,16,17,18]

In the present study, antero-posterior airway dimension remained same or slightly increased from t0 to t1 in controls which can be attributed to normal growth, whereas functional appliance treatment resulted in significant widening of the oropharynx and hypopharynx from t0 to t1. The backward position of the tongue in subjects with retrognathic mandible pushed the soft palate posterior and decreased the dimension of the upper airway. When the mandible was displaced anteriorly by the myofunctional appliance, it influenced the position of the hyoid bone and consequently the position of the tongue and thus improved the morphology of the upper airway.

During the study period, it was observed that there was no significant change in the dimensions of the nasopharynx after functional appliance therapy among all Class II malocclusion subjects. This finding is in accordance with those reported by Jena et al.,[19] Han et al.,[20] and Erbas,[21] who evaluated the effects of Twin block and MPA-IV, Bionator and Xbow respectively on airway dimensions. No significant change in nasopharynx might be due to the fact that the nasopharyngeal dimensions are associated with the actual size of adenoids which are not affected by functional orthopedic treatment.

Thus, the present study confirmed that there is a positive impact of functional appliance therapy on the airway dimension.

Hyoid bone

The hyoid bone, which is suspended by muscles and ligaments without bony articulations, plays an important role in maintaining airway dimensions and has been found to vary in position according to the position of the mandible.

In the present study, distance between hyoid bone and C3 significantly increased after myofunctional therapy and distance between hyoid bone and retrognathian significantly decreased, suggesting that the hyoid bone moved in a forward direction after functional therapy.

The hyoid bone showed a consistent forward movement with the mandible relative to the C3 level, indicating that the hyoid bone might be a contributing factor to the oropharynx enlargement. Muscles connected with the tongue or mandible to the hyoid might pull the hyoid anteriorly when the mandible and tongue were more advanced.

This is in accordance with the study by Battagel et al.[1] who found that on average, the hyoid bone moved in a forward and upward direction after mandibular protrusion, but overall they concluded that there is a wide variation in both the amount and direction of the response of the hyoid to mandibular protrusion.

The vertical position of the hyoid bone in the post-functional group data showed no significant difference from the control data, indicating that growth and development plays a vital role in vertical control of the hyoid bone. Sheng et al.[22] analyzed the hyoid bone position through a longitudinal study from the mixed dentition period to the young-adult stage and found that the hyoid bone moved downward as age increased.

The reason for a wide range of variation in change in the hyoid bone position could be attributed to the fact that the landmarks taken for measuring hyoid bone position are not stable points, but they vary with the mandibular advancement. With advancement, the mandible moves downwards, and the distance between the hyoid bone and the mandibular plane decreases; and with growth, the distance between the hyoid bone and the mandibular plane increases.[23,24] Thus, the net movement of the hyoid bone varies individually.

In the sagittal plane, the hyoid location could remain unchanged in relation to the cervical spine but varies considerably in relation to the mandible as a result of mandibular advancement or because of discrepancies in the lower jaw configuration alone. These mean changes masked a wide range of individual variation and gave no indication of the actual direction of hyoid movement in any one person.

Further studies are required with more stable parameters for measuring the actual change in hyoid bone position.

Conclusion

It was determined that the sexual dimorphism was not present for change in the pharyngeal airway dimension and the hyoid bone position in this study. The oropharynx and hypopharynx increased significantly after functional appliance therapy as compared to the control group No significant change was observed in the nasopharyx after functional appliance therapy. It could be stated the hyoid bone moved in a forward direction after functional appliance therapy, but there is a wide variation in both the amount and direction of response of the hyoid bone to mandibular advancement.

The vertical position of the hyoid bone in the post-functional group data showed no significant difference from the control data, indicating that growth plays a vital role in vertical control of the hyoid bone. A weak but positive correlation was found between increase in airway dimension and forward movement of the hyoid bone.

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A. 0-10%
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C. 25-50%
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