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Ankyloglossia: A Comprehensive Review of Pathophysiology, Diagnosis, and Management

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Abstract: ***Ankyloglossia is a congenital disorder characterised by limited tongue movement due to abnormal lingual frenum. It is often a minor anatomical difference which affects nursing, speech articulation, orofacial myofunction, craniofacial growth, occlusion and airway dynamics. This is classified as a functional spectrum disorder which cannot be diagnosed by physical appearance alone. It has many genetic, developmental, and environmental factors, has been brought to understanding by studying the embryological development. Many diagnostic classifications have been developed for functional assessment of ankyloglossia. Ankyloglossia is often associated with nursing difficulties, and surgical approach exhibits short term relief in newborns with symptoms. Therefore, its involvement in speech abnormalities and craniofacial development is inconsistent. An interdisciplinary approach includes conservative measures; surgical intervention is necessary for managing ankyloglossia. The continued debate about diagnosis and treatment approach highlights the necessity for evaluation procedure and longitudinal studies due to its clinical significance.***

Keywords: Ankyloglossia, Lingual Frenum, Tongue Mobility, Speech Articulation, Craniofacial Development

1. Introduction

Ankyloglossia is a congenital developmental disease, commonly referred to as tongue-tie, characterised by restricted lingual frenum along with restricted tongue movement. It impedes important orofacial functions like breastfeeding, swallowing, speech articulation, maintaining oral hygiene, and dentofacial development. [1] As a result, its impact in growth stages determines its clinical significance rather than its morphological appearance. [2] the tongue is vital for development of orofacial structures, neuromuscular maturation and feeding difficulties in newborn. Coordinated tongue elevation, cupping, and peristaltic movement are necessary for effective nursing. Later in life, the tongue helps with speech production, occlusal stability, dental arch growth, and maintaining a healthy oral resting position. Tongue mobility restriction at these times may lead to compensatory changes that affect craniofacial growth, articulation patterns, and feeding efficiency. [3] Ankyloglossia was mostly diagnosed based on their anatomical characteristics, which resulted in the complexity in therapeutic management. It is a benign anatomical variation resulting in the limitation of tongue movement leads to feeding difficulties which has increased emphasis on nursing physiology. [4]

Ankyloglossia is a spectrum condition, which means that the anatomy of lingual frenulum does not always reflect the functional difficulty. This functional approach has led to the development of various functional assessment tools with greater significance of interdisciplinary approach, including orthodontists, Pediatric dentists, speech-language pathologists and lactation consultants.[5] Even these advancements, there remains considerable controversy regarding diagnostic criteria, therapeutic approach, and long-term outcomes. By integrating developmental, etiological and diagnostic perspectives, this review aims to summarize the recent evidence on ankyloglossia and its evidence-based approach in clinical management. [6]

2. Developmental and Etiological Perspectives

2.1 Embryologic Development of the Tongue and Lingual Frenulum

The tongue develops between the fourth and eighth weeks of intrauterine life with phases of growth, migration, and differentiation of tissues derived from first, third and fourth pharyngeal arches. The anterior two third of the tongue originates from lateral lingual swellings derived from the first pharyngeal arch whereas copula and hypobranchial eminence gives rise to posterior one third of the tongue. [7] Myogenic precursor cells originating from occipital somites migrate into the developing tongue to form its intrinsic and extrinsic musculature, which is innervated predominantly by the hypoglossal nerve. The tongue is firmly affixed to the floor of the mouth during the early stages of development. The tongue separates from the oral floor due to progressive apoptosis, tissue remodelling, and differential growth, leaving behind the lingual frenulum, a thin midline mucosal fold. The developmental process is necessary to achieve normal tongue movement. [8] Ankyloglossia arises due to incomplete apoptosis and abnormal remodelling, which ultimately results in the long-term persistence of fibrous connective tissue which limits tongue movement like protrusion and elevation. [9]

2.2 Genetic and Hereditary Influences

The aetiology of ankyloglossia depends on the genetic factors exhibiting male predominance. [10] X-linked ankyloglossia associated with or without cleft palate has been linked with TBX22 gene mutation, which is involved in craniofacial development.[11] Reports have suggested that ankyloglossia is associated with certain syndromic disorders like orofacial digital syndrome and other craniofacial abnormalities. [12]

2.3 Environmental and Prenatal Factors

Additionally, environmental and prenatal factors also play an important role. When mothers are exposed to harmful agents like medications and illegal drugs experience nutritional deficiencies which affects the normal frenulum development

of the foetus. Since, these evidences are limited and it is mostly observational, genetic and environmental interactions are mandatory to observe the potential differences in clinical presentation.[13]

2.4 Etiological Heterogeneity and Clinical Implications

The aetiology of ankyloglossia is multifactorial, involving relationship between environmental factors, embryologic development and genetic susceptibility. Etiological heterogeneity explains the asymptomatic anatomical variations to severe functional restrictions. The understanding of aetiology of ankyloglossia supports the modern methods that emphasize functional impairment over anatomical findings and the need for individualized assessment. [13]

3. Epidemiology and Prevalence of Ankyloglossia

The prevalence of ankyloglossia ranging from 0.1% to 10%. [1] While older children are affected lesser than neonatal and infant populations. This disparity is due to underdiagnosis later in life, changes in the morphology of frenulum with growth, or spontaneous functional adaptation. The male to female gender ratio found to be 2:1 and 3:1, suggesting a possible genetic or hormonal influence. Reports of geographic and ethnic differences, and a lack of standardized diagnostic frameworks and clinical awareness causes difficulty in clinical interpretation. [14] The awareness among clinicians and a wider range of functional diagnostic tools have contributed to the increasing prevalence of ankyloglossia. [15] These patterns highlight the need for differentiating anatomical variation and clinically significant cases to prevent unnecessary intervention. [16]

4. Diagnostic Frameworks for Ankyloglossia

4.1 Clinical Examination and Functional Assessment

An assessment combining anatomical examination with functional evaluation is need for the accurate diagnosis of ankyloglossia. The lingual frenulum both in rest and movement should be assessed during clinical examination.[17] The characteristic findings of ankyloglossia includes heart shaped tongue tip, limited elevation, excessive floor-of-mouth movement and mucosal blanching. [18] The major areas to be evaluated in infants includes latch quality, tongue cupping, rhythmic peristaltic movement, co-ordination of suck-swallow-breath cycles. Additionally, maternal symptoms like nipple pain should also be evaluated. Speech articulation, swallowing patterns, tongue posture at rest, compensatory jaw or lip movements, and oral hygiene issues are all assessed in older children and adults. [19]

4.2 Objective Assessment Tools and Scoring Systems

To increase diagnostic objectivity, a number of tools have been suggested. The Coryllos classification describes anatomical insertion sites and separates anterior from posterior ankyloglossia, whereas Kotlow's classification measures the length of the free tongue and classifies severity based on frenulum attachment. Despite their widespread use, these systems show little correlation with functional outcomes and mainly rely on anatomical features. [20] Both appearance and functional parameters, such as tongue lift, extension, lateralization, and snapback, are included in functional assessment instruments like the Hazelbaker Assessment Tool for Lingual Frenulum Function (HATLFF). The LATCH score, Infant Breastfeeding Assessment Tool (IBFAT), and TABBY tool are examples of breastfeeding-specific instruments that offer information on maternal comfort and feeding efficiency. [21]

4.3 Interdisciplinary Approach to Diagnosis

Due to its multifactorial impact, an interdisciplinary diagnosis is mandatory, there should be a collaboration among paediatricians, Pediatric dentists, lactation consultants, speech-language pathologists, orthodontists, and otolaryngologists provides holistic functional assessment and reduces the risk of overdiagnosis and incorrect diagnostic intervention. This comprehensive evaluation aligns with the evidence based clinical practice supporting suitable treatment planning. [22]

5. Classification Systems of Ankyloglossia

5.1 Anatomical Classification Systems

The conventional classification system to categorise ankyloglossia was anatomical classification and remains as standard method in clinical practice. Kotlow's classification system depends on the measurement of tongue length, that is the distance from the frenulum attachment to the tip of the tongue, and divides ankyloglossia into mild, moderate, severe, and complete forms. Similarly, the Coryllos classification is based on the site of frenulum attachment and differentiates anterior and posterior tongue tie. The major limitations of these classifications lie in their reliability on anatomical appearance alone. Anatomical severity does not significantly associate with functional impairment, especially in the case of posterior ankyloglossia, where there is thick inelastic frenulum. [20]

5.2 Functional and Severity-Based Classifications

To overcome the disadvantages and limitations of Anatomical classification system, functional classification models have been developed to include mobility of the tongue and task-specific performance. The Hazelbaker Assessment Tool for Lingual Frenulum Function (HATLFF) found to be one of the functional tools, incorporating both anatomic and function scores to guide the clinical decision making. Severity based approaches demonstrates the degree of functional limitation apart from frenulum morphology only. These frameworks align with the traditional clinical practice, prioritising symptoms such as difficulty in feeding, speech difficulty, and myofunctional imbalance while determining the necessity for intervention. [21-24]

5.3 Clinical Utility and Limitations

Even though, there is multiple classification systems available, no single framework was available to completely captures the whole clinical spectrum of ankyloglossia. Numerous tools are restricted due to subjectivity, age

specificity. Consequently, classification systems should be used as a secondary diagnostic criterion, with treatment planning guided by patient specific comprehensive functional assessment. [21-24]

6. Impact of Ankyloglossia on Infant Feeding

6.1 Biomechanics of Breastfeeding and Tongue Function

Breastfeeding needs coordinated tongue elevation, anterior–posterior peristaltic movement, adequate palatal contact, and maintenance of an effective seal around the nipple–areolar complex. The tongue plays an important role in providing negative pressure and facilitates the production and transfer of milk. In ankyloglossia, the biomechanics is disrupted often resulting in inefficient suckling. To overcome this, infants may rely on increased jaw compression or increased lip tension, leads to maternal discomfort. [25]

6.2 Infant and Maternal Consequences

Those infants with ankyloglossia may present with increased feeding times, insufficient milk transfer and excessive air swallowing. Feeding related reflux symptoms in these infants are predominant. [26-28] Maternal complications include nipple pain, bleeding, recurrent mastitis, nipple cracking, and psychological distress. These difficulties ultimately result in early discontinuation of breastfeeding. [29]

6.3 Evidence for Frenotomy in Feeding Outcomes

Numerous randomised controlled trials and many systematic reviews have explored improvement in maternal nipple pain and breastfeeding measures following frenectomy procedure. Maternal satisfaction is reported following this. Therefore, evidence regarding sustained duration of breastfeeding and objective weight gain of infants, remains inconsistent. The heterogeneity and variability in methodology limit definitive conclusion, emphasising the significance of patient selection and additional lactation support. [27-30]

7. Speech and Functional Implications of Ankyloglossia

7.1 Role of Tongue Mobility in Speech Production

The articulation of speech depends precisely on the coordinated tongue movement, especially for lingual–alveolar and lingual–palatal phonemes. Adequate tongue movement is necessary for production of sounds like /t/, /d/, /l/, /n/, /r/, and sibilants. Ankyloglossia may restricts these sounds which ultimately results in articulatory distortions and reduced speech intelligibility. [31]

7.2 Variability in Clinical Presentation and Compensatory Mechanisms

Not all patients affected with ankyloglossia exhibit speech disorders. Most of them develop compensatory mechanism involving increased mandibular, labial, or pharyngeal movements that provides acceptable articulation. This variability underlines the importance of functional speech assessment. The degree of speech impairment is associated with severity of restriction, age, neuromuscular adaptability and exposure to speech therapy. [32]

7.3 Evidence Linking Ankyloglossia and Speech Disorders

The correlation between speech impairment and ankyloglossia remains controversial. Current literature evidence does not support routine frenectomy and frenectomy itself prevent future speech problems in symptomless children. The evaluation of speech language remains essential to distinguish articulation errors related to tongue restriction from phonological or developmental speech disorders. [32]

7.4 Role of Speech Therapy and Surgical Intervention

The first-line of treatment option for children affected by speech articulation problem is speech therapy. Targeted therapy may improve the mobility, strength and coordination of tongue movement in many cases which significantly improves the anatomical restriction. When significant functional limitation persists despite adequate therapy, surgical intervention is mandatory. [33]

7.5 Postoperative Rehabilitation and Long-Term Outcomes

Post surgical management includes post operative speech therapy and orofacial myofunctional therapy provides positive treatment outcome. Rehabilitation provides neuromuscular education, and enhances long-term functional improvement. Overall, speech related outcomes following these treatment interventions are most favourable when treatment is guided by interdisciplinary assessment. [34]

8. Craniofacial Growth and Occlusal Considerations

8.1 Influence of Tongue Posture on Craniofacial Development

The tongue plays an important role in shaping the craniofacial structures by its posture and functional activity. In ankyloglossia, the restriction in the mobility of the tongue may prevent adequate palatal contact of the tongue and results in forward placement of the tongue. This altered posture results in the disruption of the equilibrium of forces acting on the maxillary arch, significantly influencing the craniofacial growth patterns during developmental phase.

8.2 Association with Malocclusion and Dental Arch Abnormalities

Ankyloglossia is often associated with maxillary constriction, high arched palate, anterior open bite, mandibular incisor crowding, and increased overjet. Reduction in the movement of tongue in the constricted maxillary arch reduce the lateral expansion forces, leading to transverse restriction. These association underlines the prolonged orthodontic tongue restriction, particularly when combined with habits like improper swallowing pattern and mouth breathing. [35,36]

8.3 Myofunctional Disorders and Swallowing Patterns

Atypical swallowing, tongue thrusting has been associated with ankyloglossia. Restriction in the elevation of the tongue results in compensatory anterior and inferior tongue positioning while swallowing which influence the position of the incisor teeth and occlusal stability. If not treated during early development, these problems persist in the children. [35,36]

8.4 Airway Considerations and Functional Adaptations

The upper airway dynamics is influenced by the alteration in the tongue posture.The low resting position of the tongue result in reduced oropharyngeal airway space leads to the development of mouth breathing habit, which ultimately effects the facial growth and occlusal relationships. [35,36]

8.5 Clinical Implications for Orthodontic and Pediatric Dental Care

While evaluating the malocclusion and growth patterns, recognition of tongue -related functional influences is mandatory. Early diagnosis of ankyloglossia allows for timely intervention, including myofunctional therapy and surgical management when indicated. [35,36]**9.**

9. Management Strategies for Ankyloglossia

9.1 Principles of Clinical Decision-Making

Patient specific management should be followed for the treatment of ankyloglossia. Asymptomatic individuals can be managed by functional monitoring. Patient age, severity of functional limitation, presence of feeding and speech difficulties should be taken in consideration during treatment planning. An interdisciplinary approach is strongly recommended to ensure comprehensive treatment assessment. [37]

9.2 Conservative and Adjunctive Management

Conservative treatment options for the management of ankyloglossia includes lactation support, modification in feeding position and orofacial myofunctional therapy. Lactation counselling to parents may alleviate feeding difficulties in infants. In older children, speech therapy and myofunctional exercises can improve the strength of the tongue, functional adaptability and its coordination, it may eliminate the need for surgical intervention. [37,38]

9.3 Surgical Management: Techniques and Timing

Even after carried out conservative measures, when the functional impairment persists, surgical intervention may be indicated. Common surgical procedures include frenotomy, frenectomy, and frenuloplasty. Early intervention may be beneficial in infants with potential breastfeeding difficulties, where delayed intervention may be appropriate in older individuals following functional assessment and therapy. [39]

9.4 Laser-Assisted Frenectomy

Laser- assisted techniques such as diode therapy and Co_2 laser therapy have gained popularity due to certain advantages like decreased intraoperative bleeding, improved visibility, minimal post-operative discomfort, and faster healing. Literature evidence supports that safety and efficacy of laser-assisted frenectomy, treatment outcomes are influenced by appropriate case selection and postoperative care. [39]

9.5 Postoperative Care and Rehabilitation

Postoperative management plays an important role in success rate. Stretching exercises, tongue mobility training, and orofacial myofunctional therapy are often recommended to prevent reattachment. The rehabilitation is important to achieve optimal functional outcomes, especially in older children. [39,40]

10. Controversies and Future Directions

10.1 Ongoing Controversies in Diagnosis and Management

Ankyloglossia remains a controversial oral condition even with the increased awareness among dental diseases. The lack of clarity in standardised diagnostic criteria and assessment tools is still a matter of debate. The connection between ankyloglossia and speech disorders, craniofacial growth, and airway function remains unclear. [1,2,27]

10.2 Limitations of Current Evidence

There is limited literature source available on functional outcomes, cost-effectiveness and quality of life. The lack of standardised treatment outcome and follow – ups protocol complicates the evidence generation regarding ankyloglossia. [27]

10.3 Future Research Directions

Future research should focus on developing standard diagnostic frameworks that includes both anatomical and functional parameters. Longitudinal studies and randomised controlled trails are needed to analyse the long-term prognosis of both conservative and surgical management. Additional focus is necessary on interdisciplinary treatment models will emphasize the clinical relevance and evidence-based care. [38,40]

11. Conclusion

Ankyloglossia is a developmental condition in which the clinical significance rises beyond anatomical variation of the lingual frenulum. Studies have shown that, ankyloglossia significantly affect breastfeeding, speech clarity, orofacial muscle function, craniofacial growth, and overall quality of life. Patient centered treatment approach is mandatory while treating ankyloglossia because of its unique clinical presentation in different individuals. Although, better understanding of embryological development, improved diagnostic methods and interdisciplinary approach have enhanced the knowledge of ankyloglossia. Current reports

indicate that intervention is mainly justified when functional limitations are present where many patients benefit from conservative management and adjunct supportive therapies. When surgery is required, it should be planned carefully and followed by postoperative rehabilitation to achieve long-term treatment outcomes.

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