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CURRENT ADVANCES IN MOEBIUS SYNDROME RESEARCH: EMERGING THERAPIES AND FUTURE DIRECTION

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ABSTRACT

Moebius is a rare condition that affects the facial and eye movement muscles, making it hard for the people to smile, blink or move their eyes side to side. It usually starts from birth and is caused by problems in brain development, involving the facial (VII) and Abducens (VI) cranial nerves. People with MS may also have limb deformities, speech and feeding difficulties, and emotional challenges. The exact cause is not always known, but both genes and environmental factors during early pregnancy may play a role. Diagnosis is based on physical signs and confirmed with MRI scans and sometimes genetic testing. Treatment includes surgery (like facial reanimation), speech therapy, and orthopaedic care, depending on the persons need. New research is exploring how AI, early brain training and genetic therapies could improve diagnosis and treatment. With a team-based approach and continued innovation, the outlook for patients with Moebius syndrome is improving.

KEWORDS: Moebius Syndrome, Facial paralysis, Congenital anomalies, AI in diagnosis, speech therapy, cranial nerves.

INRODUCTION

Mobius syndrome (MS) is a rare congenital dysinnervation disorder (CCDD) that typically presents with congenital facial diplegia and impaired ocular abduction, Resulting from underdevelopment or absence of the facial (cranial nerve VII) and abducens (cranial nerve VI) nerves. First described in the late 19th century by Paul Julius Moebius, the syndrome

remains a topic of considerable interest due to its complex etiopathogenesis, varied clinical spectrum, and significant impact on patient quality of life.[23]

The prevalence of moebius syndrome [MS] is estimated at approximately 1 in 50,000 to 1 in 5,00,000 live births.[18] Despite over a century of investigation, the underlying mechanisms of MS remain elusive, with both genetic and environmental factors implicated. Advancements in prenatal imaging, magnetic resonance imaging (MRI) and genomic analysis have significantly enhances diagnostic accuracy in recent years.[47,49]

Moebius Syndrome is often associated with other congenital anomalies, such as limb malformations, Poland anomaly, clubfoot and orofacial abnormalities. The multisystem involments necessitates an interdisciplinary approach involving pediatric neurology, genetics, craniofacial surgery, ophthalmology, and speech- language pathology.[34] This comprehensive review aims to synthesize the latest evidence surrounding moebius syndrome, with a specific focus on emerging therapies, diagnostic advancement.

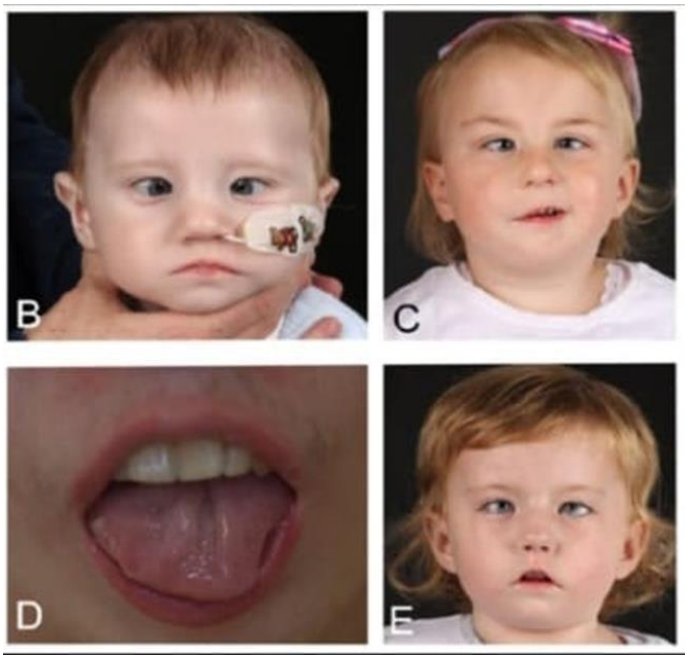

Fig. 1: Facial and oral signs of moebius syndrome in children's.

1. ETIOLOGY

The etiology of moebius syndrome is multi factorial and remains incompletely understood. Traditionally, the syndrome was considered to result from congenital hypoplasia or agenesis of the facial (VII) and Abducens (VI) Cranial nerve nuclei, but advances in neuropathology, genetic and Embryology have expanded this view significantly. Current Literature suggest

both Genetic and Environmental factors, acting independently or synergistically, contribute to its development.

1.1 Genetic causes

Although most moebius syndrome cases are sporadic, familiar instances have been reported, supporting a genetic basis in some cases. Mutations in the PLXND1 and REV3L genes were identified in De nova cases and are currently among the most robust genetic findings associated with the disorder.[40] These genes play a role in:

- PLXND1 encodes for a semaphoring receptor involved in axonal guidance
- REV3L encodes a DNA polymerase, crucial for DNA repair mechanisms during rapid neurogenesis.

Chromosomal detections have also been implicated, such as 3q21 deletions, which can produce a phenotype mimicking unilateral congenital facial paralysis, further complicating differential diagnosis.[46]

Recent gene expression studies and whole-exome sequencing have further identified candidate loci associated with rhomb encephalic mal development, including the hindbrain structures where cranial nerve nuclei developed.[30,31]

1.2 Teratogenic and latrogenic influences

Additional environmental risk factors or teratogens have postulated:

- Cocaine, alcohol, and Benzodiazepines have been weakly associated in some studies.
- Maternal illness during pregnancy, such as diabetes mellitus, has also been linked to increased risk of neural tube and craniofacial anomalies.

However, no direct causalities have been proven in the majority of such exposures, and many cases remain idiopathic.[36,42]

1.3 Familial Patterns and inheritance

Though most cases are sporadic, rare reports of familial clustering suggest autosomal dominant, recessive or x-linked inheritance of some forms. Specific syndromic overlaps with Poland syndrome, HCFP (Hereditary Congenital Facial palsy), and other congenital cranial dysinnervation disorders (CCDDs) further complicate inheritance modeling.[32,33]

1.4 Neuropathological evidence

Towfighi et al.[28,44] and Pitner et al.[35] provided post mortem neuropathological evidence that supports the nuclear hypoplasia and brain stem lesions theory, including:

- Absence or hypoplasia of the facial and abducens nuclei
- Gliosis and necrosis in brainstem
- Peripheral nerve involvement

These findings align well with both vascular and genetic hypothesis and confirm that MS is a disorder of neurodevelopmental origin, often arising in first six week of gestation.

Table 1: Summary of Etiological Factors.

Etiological factors	Genetic mutation	teratogens	Neuropathological lesions	Familial Inheriance	Embryological timings
Examples/ Mechanism	PLXND1, REV3L,3q21 deletions	Cocaine, Alcohol, mifepristone	Nuclear hypoplasia, ischemic injury	Rare autosomal dominant/recessive patterns	Disruption between 4-7 weeks gestation
Reference	[40],46],[30]	[42], [36]	[28], [35], [44]	[32, 33]	[30], [31], [35]

2: PATHOPHYSIOLOGY

2.1 Cranial nerve involvement

The defining pathological feature of MS is the hypoplasia or Aplasia of the sixth and seventh cranial nerve nuclei.[28,35,44] Studies using brain MRI and postmortem evaluation reveal:

- Absence of the facial colliculus
- Hypoplasia of the pons and medulla
- Poorly formed cranial nerve tracts

These findings corelate with the clinical manifestations such as strabismus, lack of facial expression, and feeding difficulties.

2.2 Radiological findings

MRI studies have shown

- Brainstem hypoplasia
- Absence or thinning of the facial nerves
- Abnormal pontine tegmentum[47,48,49]

In prenatal settings, sonographic features like micrognathia, cleft palate and limb anomalies can also suggest a diagnosis.[50,51,52]

3. CLINICAL FEATURES

3.1 Cranial nerve palsy

The most consistent and defining features of Moebius syndrome is congenital, Bilateral facial palsy, resulting in mask like facies, abscens of facial expression, incomplete eye closure or lagophthalmos.[20,21,34]

Some patients also display involvement of other crania nerves trigeminal(V), Glossopharyngeal(IX), Vagus (X), Hypoglossal (XII).[30,34,35]

3.2 Orofacial and feeding abnormalities

Feeding and swallowing difficulties are commonly observed in infancy due to poor sucking reflex, tongue hypomotility or atrophy, palatal and mandibular malformations.[38,39,46] Speech delays are often present due to poor lip and tongue movement. Oral anomalies such as higharched palate, micrognathia and cleft palate may coexist.[20,38]

3.3 Musculoskeletal deformities

Poland syndrome (hypoplasia of pectoral muscle and upper limb anomalies) is found in ~15% of MS patients.[27,53] Congenital limbs anomalies – club foot, syndactyly, brachydactyly[30,36,53], scoliosis and thoracic cage deformities in some cases.[26,31] These features often suggest a disruption sequence during embryonic development rather than an isolated genetic mutation.[42,43]

3.4 Associated systemic features

Other systemic features may include congenital heart defects (e.g.: ventricular septal defects)[37], hearing loss (sensorineural or conductive)[34], epileptic seizures (rare)[31], hypoplastic tongue or bifid uvula[38,39], respiratory complication in infancy due to aspiration or weak cough reflex.[36,39]

4. COMORBIDITIES AND ASSOCIATED ANOMALIES

4.1 Craniofacial anomalies

Patients often exhibit craniofacial dysmorphisms including micrognathia, cleft palate, higharched palate, dental malocclusion, and asymmetry of facial bones.[14,39,48] These anomalies complicate feeding, speech and social integration, often requiring early surgical or orthodontic intervention.

4.2 Ophthalmologic and speech abnormalities

Impaired lateral eye movement due to abducens nerve palsy can result in strabismus, lagophthalmos and poor blinking reflex, which predisposed to corneal ulceration and dry eye syndrome.[48,49] Up to 70% of individuals present with dysphagia, hypotonia of oral muscles and articulatory speech disorders.[14,39]

4.3 Neurodevelopmental and psychiatric comorbidities

Several studies document association with autism spectrum disorder (ASD)[14,33], ADHD and other behavior disorders, cognitive delays or intellectual disability in a minority. These findings underscore the need for early neurophysiological assessment.[33,34]

4.4 Cardiac anomalies

Some cases of moebius syndrome are associated with congenital hear defects such as atrial septal defects and patent ductus arteriosus.[37] Genitourinary anomalies and hearing impairment have also been documented in a minority of cases.[16]

5. DIAGNOSIS

The diagnosis of MS is primarily clinical, supported by neuroimaging and genetic testing.

- Clinical criteria: Diagnosis requires congenital facial palsy and limited ocular abduction, with or without additional anomalies.[33]
- Imaging: MRI is essential to confirm hypoplasia or agenesis of the facial colliculi and other brainstem anomalies.[47,49] Prenatal imaging using ultrasonography and fatal MRI has also been successful in identifying characteristic features in utero.[50,52]
- Genetic testing: Targeted gene panel and whole exome sequencing can identify mutation in PLXND1, REV3L and other candidate's genes.[40] However no single gene mutation is diagnostic for all cases.
- Differential diagnosis: Conditions that mimic MS include congenital facial palsy due birth trauma, hereditary congenital facial paresis (HCFP), and other CCDDs.[29,32]

6. IMPACT ON QUALITY OF LIFE

Moebius syndrome significantly impacts multiple dimensions of life- physical, emotional, social and physiological -across all age groups.[20,30,33,34]

Emotional and social challenges: facial paralysis hinders non verbal communication, often leading to misinterpretation of emotions, social withdraw, bullying and stigma.[20,33,34,54]

children especially face difficulties in peer bonding and self-esteemed.[34] **Communication and feeding issues:** dysarthria, delayed speech and oromotor dysfunction limit verbal expression and early feeding, affecting academic and social performance. Speech therapy can improve these outcomes.[34,38,39,44] **Mental health**: anxiety, depression, poor body image, and social phobia are more prevalent in MS, particularly during adolescence. Early intervention and family support are key to psychological resilience.[33,34,54] **Adult life and careers**: adults may face employment and relationship challenges due to expressive limitations, yet many achieve independence with adequate psychosocial support.[34,54] **Caregiver burden:** caregivers often report emotional and logistical strain due to complex medical needs. Coordinated, multidisciplinary care improves outcomes for families.[30,34,38]

7. EMERGING THERAPIES AND INTERVENTIONS

Although there is currently no cure for Moebius Syndrome, recent advances in neuroplasticity, surgical innovation, and genetic understanding have revolutionized management. Treatment is highly individualized and often multidisciplinary, including neurologist, surgeons, speech therapists and psychologists.

7.1 Surgical Interventions

7.1.1 Facial reanimation Surgery

Facial reanimation remains a cornerstone in managing facial palsy. Temporalis muscle transfer and cross-facial nerve grafts have been used successfully. A new dynamic gracilis free-muscle flap innervated by the masseteric nerve has shown improved outcomes in dynamic smile restoration.[54] Long- term studies suggest significant improvement in social interaction and self-esteemed.[26]

7.1.2 Ocular and oral surgical interventions

Strabismus correction, eyelid surgeries and palatal repairs maybe necessary for patients with incomplete eye closure, cleft palate, or other oral anomalies.[39] Orofacial myofunctional therapy is frequently combined with surgical approaches to improve speech and swallowing

7.2 Neurodevelopmental speech therapy

Early speech therapy, starting in infancy, enhances communication skills and reduces long-term impairment. studies by Picciolini et al. emphasized early developmental intervention to improve oromotor function and social cognition.[14] Multisensory stimulation and motor training exercises are critical for maximizing neuroplasticity during early childhood.[3,6]

7.3 Orthopedic and limb management

Children with limb anomalies such as syndactyly, club foot, hypoplasia benefit from early orthopedic interventions. Prosthetics, tendon release procedurs and physical therapy are integral components of the rehabilitation plan.[5,15]

7.4 Emerging pharmacologic approaches

Although no pharmacological cure exists, research is underway targeting pathways involved in neural development. Animal studies targeting HOXA1 and PLXND1 mutation have shown potential for modulating crania nerve development.[40]

8. FUTURE DIRECTION IN RESEARCH AND THERAPIES

8.1 Genetic insights and personalized medicine

Future research may explore CRISPR-Cas 9 or RNA-based interventions to correct developmental gene disruptions. Epigenetic factors and maternal exposures (e.g.: Misoprostol) are also under active investigation.[42]

8.2 Neurodevelopmental plasticity and early intervention

Studies underscore the brain's potential for neuroplasticity when exposed to structured early interventions. In cooperating virtual reality, AI based therapy platforms, and gamified motor skills training can redefined pediatric neurorehabilitation.[2,4,6]

8.3 AI and Imaging in Diagnosis

Machine learning models have begun to assist in analyzing craniofacial morphologies and interpreting brain stem imaging.[2] Integration of AI with prenatal ultrasound and fatal MRI may allow early risk prediction, aiding in preventive counselling and management.

8.4 Cross-Cultural and epidemiological research

There is a need for better epidemiological studies, especially underreported region. Most studied come from western populations; However, global data on environmental teratogens, familial inheritance, and healthcare access disparities are vital to comprehensive understanding.[1,6,13]

9. CONCLUSION

Moebius Syndrome represents a complex neurodevelopmental disorder with a highly variable phenotype involving cranial nerve dysfunction, limb anomalies, and neurodevelopmental delay. Although the core diagnostic criteria remain rooted in facial and abducens palsy,

modern diagnostic tools, including MRI and genetic testing, allow a more nuanced understanding

Emerging therapies-particularly surgical innovation, genetic research and early neurodevelopmental intervention are improving quality of life and functional independence for patients. Future research must focus on the integration of AI in diagnostics, exploration of genetargeted therapies, and a deeper understanding of teratogenic influences.

As our understanding of the molecular and developmental basis of MS expands a multidisciplinary, personalized care approach remains essential for improving outcomes.

Comprehensive care, early intervention and continues research into emerging technologies will determine the next frontier in managing this rare but impactful disorder.

REFERENCE

1. Bavin EL, Lette MG, Dew A, Oates J, Wall L. Communication and psychosocial adjustment outcomes for children with Moebius syndrome. Int J Speech Lang Pathol, 2020; 22(6): 657–66. https://pubmed.ncbi.nlm.nih.gov/33191114/
2. Suskind DL, Glinow A, Hurvitz K, et al. A Narrative Review of Moebius Syndrome. OTO Open, 2023; 7(1): 1-8. https://journals.sagepub.com/doi/full/10.1177/2329048X231205405
3. Iyer S, Amin S, Waggoner D, et al. Moebius syndrome: A case report and literature review. BMC Pediatr, 2022; 22(1): 295. https://bmcpediatr.biomedcentral.com/articles/10.1186/s12887022-03803-3
4. Taksande A, Vilhekar K. Moebius Syndrome Associated with Cardiovascular and Skeletal Abnormalities: A Rare Case Report. SAGE Open Med Case Rep., 2024; 12: 2050313X241271857. https://journals.sagepub.com/doi/full/10.1177/2050313X241271857
5. Picciolini O, Porro M, Cattaneo E, et al. Moebius Syndrome: A Review of the Literature. Int J. Environ Res Public Health, 2020; 17(15): 5528. https://www.mdpi.com/1660-4601/17/15/5528
6. Mangaraj M, Sharma V, Biswal A, et al. Möbius Syndrome: A Rare Entity or a Missed Diagnosis? J Pediatr Neurosci, 2023; 18(1): 21–28. https://pubmed.ncbi.nlm.nih.gov/38321523/

7. Gutowski NJ, Chilton JK. The congenital cranial dysinnervation disorders. Arch Dis Child., 2015; 100(7): 678–681. https://doi.org/10.1136/archdischild-2015-310043
8. Romanini MV, Calevo MG, Puliti A, et al. Poland syndrome: A proposed classification system and perspectives on diagnosis and treatment. Semin Pediatr Surg., 2018; 27(3): 189–199. https://doi.org/10.1053/j.sempedsurg.2018.05.006
9. Verzijl HTFM, van der Zwaag B, Cruysberg JRM, Padberg GW. Möbius syndrome redefined: A syndrome of rhombencephalic maldevelopment. Neurology, 2003; 61(3): 327–333. https://doi.org/10.1212/01.WNL.0000078891.53620.85
10. Verzijl HTFM, Valk J, de Vries R, Padberg GW. Radiologic evidence for absence of the facial nerve in Möbius syndrome. Neurology, 2005; 64(5): 849–855. https://doi.org/10.1212/01.WNL.0000152980.92436.D9
11. Pedraza S, Gámez J, Rovira A, et al. MRI Findings in Möbius syndrome: Correlation with clinical features. Neurology, 2000; 55(4): 1058-1060. https://doi.org/10.1212/WNL.55.7.1058
12. Kim N, Kim JH, Kim J-S, Hwang J-M. Möbius syndrome: Clinico-radiologic correlation. Graefes Arch Clin Exp Ophthalmol, 2018; 256(11): 2219-2223. https://doi.org/10.1007/s00417018-4089-3
13. Yoon K, Yoo SJ, Suh DC, et al. Möbius syndrome with brain stem calcification: Prenatal and neonatal sonographic findings. Pediatr Radiol, 1997; 27(2): 150–152. https://doi.org/10.1007/s002470050088
14. Sherer DM, Spafford P. Prenatal sonographic evidence supporting an in utero developmental etiology of Möbius sequence. Am J Perinatol, 1994; 11(2): 157-159. https://doi.org/10.1055/s2007-994578
15. Nguyen GV, Goncalves LF, Vaughn J, et al. Prenatal diagnosis of Poland-Möbius syndrome by multimodality fetal imaging. Pediatr Radiol, 2023; 53(10): 2144–2148. https://doi.org/10.1007/s00247-023-05712-8
16. Kuklík M. Poland-Möbius syndrome and disruption spectrum affecting the face and extremities: A review paper and presentation of five cases. Acta Chir Plast, 2000; 42(3): 95-103. https://pubmed.ncbi.nlm.nih.gov/11059047/
17. Simmons JK, Nadeem W, Salehi PP, Azizzadeh B. A New Technique in Facial Reanimation Surgery for Moebius Syndrome. Facial Plast Surg Aesthet Med., 2024. https://doi.org/10.1089/fpsam.2023.0541
18. Orphanet. Möbius Syndrome – Summary for Clinicians. 2023. Available from: https://www.orpha.net/consor/cgi-bin/OC_Exp.php?lng=EN&Expert=654

19. Verywell Health. Möbius Syndrome Overview, 2023. Available from: https://www.verywellhealth.com/moebius-syndrome-overview-5118477
20. Strömland K, Sjögreen L, Miller M, Gillberg C, Wentz E, Johansson M, et al. Möbius sequence--a Swedish multidiscipline study. Eur J Paediatr Neurol., 2002; 6(1): 35-45. Available from: https://pubmed.ncbi.nlm.nih.gov/11853187/
21. Kumar D. Moebius syndrome. J Med Genet, Feb. 1990; 27(2): 122-6.
22. Von Graefe A, Saemisch T. Handbuch der gesammten Augenheilkunde. Leipzig: W Engelman, 1880; 6: 60.
23. Möbius PJ. Über angeboren doppelseitige Abducens-Facialis-Lähmung. Münch Med Wochenschr, 1888; 35: 91–4.
24. Möbius PJ. Über infantilen Kernschwund. Münch Med Wochenschr, 1892; 39: 17–21, 41–3: 55–8.
25. Henderson JL. The congenital facial diplegia syndrome: clinical features, pathology and etiology. Brain., 1939; 62: 381–403.
26. McClure KM, Kilinc E, Oishi S, Riccio AI, Karol LA. Möbius Syndrome: A 35-Year Single Institution Experience. J Pediatr Orthop, 2017; 37(7): e446–e449. Available from:https://pubmed.ncbi.nlm.nih.gov/27556884/
27. Sugarman GI, Stark HH. Möbius syndrome with Poland's anomaly. J Med Genet., 1973; 10(2): 192–6. Available from: https://pubmed.ncbi.nlm.nih.gov/4265795/
28. Towfighi J, Marks K, Palmer E, Vannucci R. Möbius syndrome: Neuropathologic observations. Acta Neuropathol, Oct. 1979; 48(1): 11–7. Available from: https://pubmed.ncbi.nlm.nih.gov/117353/
29. May M, Schaitkin BM. Facial nerve disorders in newborns and children. In: May M, Schaitkin BM, editors. The Facial Nerve. 2nd ed. New York: Thieme.
30. Verzijl HTFM, van der Zwaag B, Cruysberg JRM, Padberg GW. Möbius syndrome redefined: A syndrome of rhombencephalic maldevelopment. Neurology, 2003; 61: 327–33. Available from: https://doi.org/10.1212/01.WNL.0000078936.94493.A2
31. Verzijl HTFM, van der Zwaag B, Lammens M, Donkelaar HJT, Padberg GW. The neuropathology of hereditary congenital facial palsy vs Möbius syndrome. Neurology, 2005; 64: 649–653. Available from: https://doi.org/10.1212/01.WNL.0000151855.30765.7C
32. Gutowski NJ, Chilton JK. The congenital cranial dysinnervation disorders. Arch Dis Child., 2015; 100: 678–681. Available from: https://doi.org/10.1136/archdischild-2014-307332

33. Bell C, Nevitt S, McKay VH, Fattah AY. Will the real Moebius syndrome please stand up? A systematic review. Am J Med Genet A., 2018; 176(11): 257–265. Available from: https://doi.org/10.1002/ajmg.a.38575
34. McKay VH, Touil LL, Jenkins D, Fattah AY. Managing the child with a diagnosis of Moebius syndrome: More than meets the eye. Arch Dis Child., 2016; 101: 843–846. Available from: https://doi.org/10.1136/archdischild-2015-310043
35. Pitner SE, Edwards JE, McCormick WF. Observations on the pathology of the Moebius syndrome. J Neurol Neurosurg Psychiatry, 1965; 28: 362–74. Available from: https://jnnp.bmj.com/content/28/4/362
36. Singh A, Sachan R, Rawat M. Moebius syndrome in an infant with fetal misoprostol and mifepristone exposure. Pediatr Oncall J., 2016; 13: 44–5. Available from: https://www.pediatriconcall.com/pediatric-journal/view/fulltext-articles/973/J/0/0/437/0
37. A. Möbius syndrome associated with acyanotic congenital heart disease in a neonate. J Mahatma Gandhi Inst Med Sci., 2014; 19: 138.
38. Singh P, Gupta SB, Kumar R, Agarwal R, Singh DP, Verma D. Moebius syndrome: a case report. Int J Med Res Rev., 2014; 2: 624–6.
39. Ana SC, Tatiana VB, Vera CLSR, et al. Moebius syndrome: a case with oral involvement. Cleft Palate Craniofac J., 2008; 45: 319–24. https://pubmed.ncbi.nlm.nih.gov/18454697/
40. Tomas-Roca L, Tsaalbi-Shtylik A, Jansen JG, et al. De novo mutations in PLXND1 and REV3L cause Möbius syndrome. Nat Commun, 2015; 6: 7199.
41. OMIM Entry #157900: Moebius syndrome. https://www.omim.org/entry/157900
42. Pastuszak AL, Schuler L, Speck-Martins CE, et al. Use of misoprostol during pregnancy and Möbius' syndrome. N Engl J Med., 1998; 338: 1881–5. Available from: https://www.nejm.org/doi/full/10.1056/NEJM199806253382602
43. Serge O, Gaurav S, Sherri B. Moebius syndrome. Am J Neuroradiol, 2005; 26: 430–2. Available from: http://www.ajnr.org/content/26/2/430
44. Towfighi J, Marks K, Palmer E, Vannucci R. Moebius syndrome: neuropathologic observations. Acta Neuropathol, 1979; 48: 11–7. [Same as #28]
45. Volpe JJ, editor. Volpe's neurology of the newborn. 6th ed. Amsterdam: Elsevier, 2017; 690–1.
46. Aslan N, Sivrice C, Ormeki AR. The differential diagnosis of a patient with unilateral congenital facial paralysis: 3q21 deletion. Acad J Pediatr Neonatol, 2018; 6: 555743. from: https://juniperpublishers.com/ajpn/pdf/AJPN.MS.ID.555743.pdf

47. Pedraza S, Gámez J, Rovira A, et al. MRI Findings in Möbius syndrome: Correlation with clinical features. Neurology, 2000; 55(4): 1058–60. https://doi.org/10.1212/WNL.55.7.1058
48. Kim N, Kim JH, Kim J-S, Hwang J-M. Möbius syndrome: Clinico-radiologic correlation. Graefes Arch Clin Exp Ophthalmol, 2018; 256(11): 2219–23. https://doi.org/10.1007/s00417-018-4089-3
49. Verzijl HTF, Valk J, de Vries R, Padberg GW. Radiologic evidence for absence of the facial nerve in Möbius syndrome. Neurology, 2005; 64(5): 849–55.
50. Yoon K, Yoo SJ, Suh DC, et al. Möbius syndrome with brain stem calcification: Prenatal and neonatal sonographic findings. Pediatr Radiol, 1997; 27(2): 150–2.
51. Sherer DM, Spafford P. Prenatal sonographic evidence supporting an in utero developmental etiology of Möbius sequence. Am J Perinatol, 1994; 11(2): 157–9. https://doi.org/10.1055/s-2007-994578
52. Nguyen GV, Goncalves LF, Vaughn J, et al. Prenatal diagnosis of Poland-Möbius syndrome by multimodality fetal imaging. Pediatr Radiol, 2023; 53(10): 2144–8. https://doi.org/10.1007/s00247-023-05712-8
53. Kuklík M. Poland-Möbius syndrome and disruption spectrum affecting the face and extremities: a review paper and five cases. Acta Chir Plast., 2000; 42(3): 95–103. https://pubmed.ncbi.nlm.nih.gov/11059047/
54. Simmons JK, Nadeem W, Salehi PP, Azizzadeh B. A New Technique in Facial Reanimation Surgery for Moebius Syndrome. Facial Plast Surg Aesthet Med., 2024.