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REVIEW ARTICLE

Approach to a Child with Cleft Lip and Palate (CLP) – Perinatal Management: A Narrative Review

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Cleft Lip and Palate, Congenital Craniofacial Anomalies, Perinatal Management, Multifactorial Etiology, Prenatal Diagnosis, Multidisciplinary Approach

ABSTRACT

Cleft lip and palate (CLP) are among the most common congenital craniofacial anomalies, affecting approximately 1 in 700 births globally. This narrative review discusses the multifactorial etiology of CLP, including genetic predisposition and environmental triggers such as maternal smoking, alcohol use, and nutritional deficiencies. The importance of early diagnosis through prenatal ultrasonography and the role of a multidisciplinary approach in managing CLP are emphasized. Early identification allows for timely intervention, specialized feeding methods, and parental counseling, which can significantly reduce anxiety and improve outcomes.

The review highlights the critical role of a multidisciplinary cleft team, comprising plastic surgeons, pediatricians, speech therapists, orthodontists, and other specialists, in providing comprehensive care. This team approach ensures coordinated surgical repairs, ongoing support for feeding, hearing, speech development, and psychosocial well-being. The manuscript also explores the various surgical techniques for lip and palate repair, the use of specialized feeding bottles, and the importance of speech therapy and orthodontic care in the long-term management of CLP.

Additionally, the review addresses the challenges faced in India, where a substantial number of infants are born with clefts each year. It underscores the need for raising awareness, improving access to specialized care, and supporting families through government programs and NGO initiatives. The future trends in cleft care, including tissue engineering, 3D printing, and the application of artificial intelligence, are also discussed, offering hope for improved outcomes and reduced treatment burdens.

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INTRODUCTION

Cleft lip and palate (CLP) are congenital craniofacial anomalies in which there is an opening (cleft) in the upper lip, the palate (roof of mouth), or both. A cleft lip results from failure of the medial nasal prominences to fuse with the maxillary prominences during weeks 4–6 of gestation, leading to a gap in the upper lip (which may extend into the nose and gum).[1] A cleft palate occurs when the palatal shelves (which normally fuse by weeks 8–12) fail to join, leaving an opening in the hard and/or soft palate Clefts can be unilateral or bilateral and may occur in isolation (cleft lip only or cleft palate only) or in combination (cleft lip with cleft palate). Orofacial clefts cause functional problems with feeding, swallowing, speech, and hearing, along with facial deformity.[2] Less than half of cases have other associated anomalies; most are isolated birth defects. Considering recent literature evidence, this narrative review provides a comprehensive overview of the multifactorial etiology, early diagnosis, and multidisciplinary management of cleft lip and palate (CLP).

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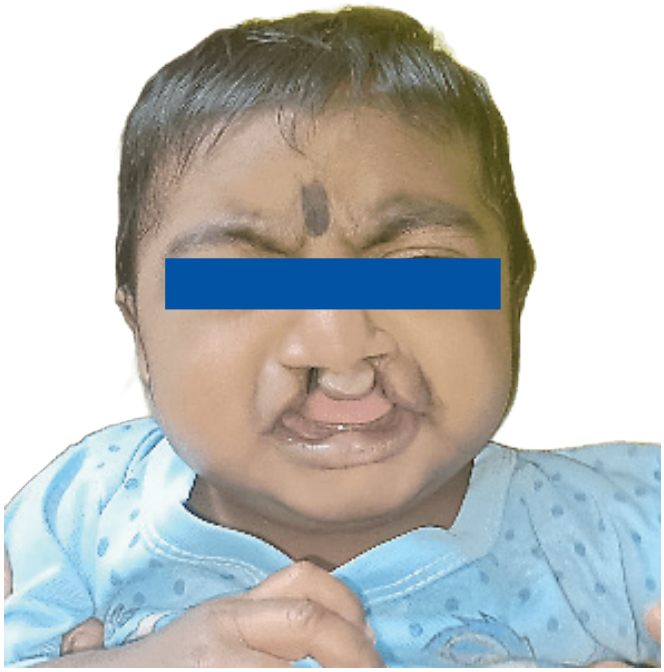

Figure 1: An infant with an unrepaired bilateral cleft lip and palate, illustrating the extent of the cleft involving the lip and nostril.

It emphasizes the importance of early identification through prenatal ultrasonography and the role of a multidisciplinary cleft team in providing coordinated care.

MATERIALS AND METHODS

To facilitate this narrative review on the perinatal management of cleft lip and palate (CLP), a comprehensive literature search was conducted using PubMed. The search strategy involved using key words such as "Cleft Lip and Palate (CLP)," "Congenital Craniofacial Anomalies," "Perinatal Management," "Multifactorial Etiology," "Prenatal Diagnosis," "Multidisciplinary Approach," "Surgical Techniques," "Specialized Feeding Methods," "Speech Therapy," "Orthodontic Care," "Genetic Predisposition," "Environmental Triggers," "Tissue Engineering," "3D Printing," "Artificial Intelligence," "India," "Government Programs," and "NGO Initiatives." Relevant articles were identified and reviewed to gather current evidence and insights on the etiology, diagnosis, and multidisciplinary management of CLP. The selected literature provided a foundation for discussing the importance of early identification, the role of a multidisciplinary cleft team, various surgical techniques, and long-term management strategies. Additionally, the review addressed specific challenges and future trends in cleft care, particularly in the context of India.

DISCUSSION

Epidemiology: Cleft lip ± palate is among the most common birth defects worldwide. Global prevalence is roughly **1 in 700 births**, though estimates range from about 1 in 600 to 1 in 1000 newborns.[2,3] The incidence varies by ethnicity and region – it is higher in Asian populations and lower in Africans.[4] For example, one review found cleft lip with or without palate in 1.0–1.5 per 1000 live births globally.[3] Isolated cleft palate is less common (around 1 in 2,500 births. In India, with ~24–25 million births annually, an estimated 27,000–33,000 babies are born with clefts each year. Indian hospital-based studies report cleft lip with or without palate in roughly 0.9–1.3 per 1000 live births. The Indian subcontinent thus bears a substantial burden – approximately 3 infants with cleft are born every hour. Cleft lip ± palate is more common in males, especially left-sided unilateral clefts, whereas isolated cleft palate is more frequent in females.

Importance of Early Diagnosis & Multidisciplinary Approach: Early identification of a cleft – whether prenatally or at birth – is crucial for timely intervention and parental preparation. Detecting a cleft on antenatal ultrasound allows the healthcare team to plan for specialized feeding methods and any immediate airway needs at delivery. It also enables early counseling of the family about the treatment course. Studies show that prenatal counseling (meeting the cleft team, learning feeding techniques) can reduce parental anxiety and even avoid unnecessary NICU admissions for feeding issues.[5] Once the baby is born, a multidisciplinary cleft team approach is considered best practice. The combined expertise of plastic surgeons, pediatricians/neonatologists, speech therapists, otolaryngologists (ENT), orthodontists, dentists, audiologists, genetic counselors, nurses, and psychologists/social workers is needed to address the multiple challenges over time.[2] Coordinated team care ensures that surgical repairs are timed appropriately and that the child receives ongoing support for feeding, hearing, speech/language development, dental occlusion,

and psychosocial well-being. In India, specialized cleft centers and initiatives (including support from NGOs like Smile Train) have improved access to multidisciplinary cleft care, though rural-urban disparities remain. Early diagnosis and a team-based long-term management plan greatly improve outcomes–enabling most children with CLP to achieve normal feeding, speech, and an acceptable aesthetic result, thus leading healthy lives integrated into society.

ETIOLOGY AND RISK FACTORS

Multifactorial Etiology: The causes of cleft lip and palate are multifactorial, involving both genetic predisposition and environmental triggers. The majority of CLP cases are non-syndromic (isolated) polygenic disorders – meaning multiple genes contribute to a susceptibility, which in combination with certain maternal environmental exposures can result in a cleft. Numerous candidate genes (e.g., IRF6, MSX1, PVRL1, etc.) have been investigated, but the genetic architecture is complex. Concordance in monozygotic twins is significantly higher than in dizygotic twins, supporting a genetic component.

Recurrence risk in families is elevated: having one affected child increases the chance for clefts in subsequent children, and the risk rises further if two are siblings.

Syndromic vs. Non-syndromic: Around *5–15%* of orofacial clefts are part of an identifiable syndrome or cluster of anomalies.

Over 600 genetic syndromes can include clefting. For example, clefts are seen in Pierre Robin sequence (micrognathia, glossoptosis, cleft palate), Van der Woude syndrome (lip pits), 22q11.2 deletion syndrome (velocardiofacial syndrome), Treacher Collins, Apert syndrome, and others. Syndromic cases are more likely with isolated cleft palate than with cleft lip. In nonsyndromic clefts, the vast majority of cleft lip ± palate and about half of cleft palates, no other anomalies are present. Nonetheless, even non-syndromic CLP has genetic risk factors; for instance, there is often a male predominance in cleft lip ± palate and a tendency for left-sided clefts.

Environmental Risk Factors: A number of maternal exposures and conditions during early pregnancy are linked to higher risk of orofacial clefts. Key factors during the critical period of lip and palate formation (4^{th} –12^{th} week of gestation) include:

- **Maternal smoking:** Tobacco use or significant second-hand smoke exposure in early pregnancy is a well-established risk factor, roughly doubling the risk of cleft lip/palate.
- **Alcohol use:** Prenatal alcohol consumption has also been associated with increased cleft risk in some studies.
- **Nutritional deficiencies:** Poor maternal nutrition, especially folic acid deficiency or overall lack of multivitamins, has been investigated. Unlike neural tube defects, the link between folate and clefts is less clear, but some evidence suggests folate insufficiency may contribute. In India, one case-control study found that mothers with exclusive vegetarian diets (possibly low in certain vitamins like B12/folate) had a higher odds of having a baby with cleft (AOR ~4.5). However, routine periconceptional folic acid supplementation did not show a statistically significant protective effect in that study.[6]
- **Medications and teratogens:** Certain drugs taken in the first trimester can induce clefts. Notably, anti-epileptic drugs (anticonvulsants such as phenytoin, valproic acid, topiramate) have been associated with orofacial). Isotretinoin (Vitamin A derivatives) and methotrexate are other known teratogens that can cause clefting among other defects.
  - **Maternal illness and other factors:** Pregestational diabetes and obesity have been identified as risk factors for clefts. High maternal age (older mothers) may slightly increase the risk. Maternal infections (like certain viral illnesses) or exposure to chemicals/pesticides have also been implicated. Consanguinity (in some Indian populations) could increase the chance of recessive gene factors coming together, potentially contributing to cleft occurrence as well. [6]

It is important to note that in most individual cases, no single cause is identified – rather, a combination of a susceptible genetic background with one or more environmental hits leads to the cleft. For instance, a family history of CLP confers a high risk (one Indian study showed an OR >15 for family history), and if such a predisposed fetus is exposed to smoking or poor nutrition in utero, the likelihood of cleft

formation is further increased. Continued research is focusing on gene-environment interactions in cleft etiology. Ultimately, understanding these factors aids in prevention strategies (e.g., smoking cessation, nutritional counseling for pregnant mothers) and in offering genetic counseling to families about recurrence risks.

PRENATAL DIAGNOSIS AND COUNSELING

Role of Ultrasonography: High-resolution ultrasound (USG) in mid-pregnancy is the primary tool for prenatal detection of cleft lip/palate. A detailed anomaly scan around 18–20 weeks gestation can identify most cleft lips. The classic ultrasound finding is a disruption in the continuity of the upper lip on a coronal view of the fetal face. With an experienced sonographer, the detection rate for cleft lip (with or without palate) is quite high – studies report 88–93% sensitivity for cleft lip ± palate on second-trimester ultrasound.[7] Three-dimensional ultrasound can further enhance visualization; in specialized centers, 3D US has achieved near 100% detection of cleft lips and up to ~86–90% for combined cleft lip and palate.[8] Isolated cleft palate, however, is extremely difficult to diagnose with prenatal ultrasound alone. The fetal palate is hard to visualize and subtle clefts of the soft palate may not be seen. Reported detection rates for isolated cleft palate are as low as 0–1% on routine US[9] – in other words, most isolated palatal clefts are missed prenatally and only discovered after birth. Because of this limitation, whenever a cleft lip is seen on ultrasound, it is often challenging to determine the involvement of the palate. Clues like polyhydramnios (excess amniotic fluid due to poor fetal swallowing) or an abnormal profile might raise suspicion of a cleft palate, but definitive diagnosis of a palate cleft in utero remains difficult via sonography alone.

Fetal MRI and Advanced Imaging: Fetal MRI can be a useful adjunct in cases where a cleft is suspected, especially to delineate the extent of palate involvement. MRI is not hindered by fetal bone shadowing or fetal position as much as ultrasound, so it can directly visualize the integrity of the lip and palate in multiple planes. For complex cases (for example, suspicion of a Pierre Robin sequence or other craniofacial syndromes), MRI can help confirm a cleft palate or reveal associated abnormalities (like brain anomalies). It is sometimes specifically requested if the ultrasound suggests a cleft palate or if other anomalies (e.g., fetal heart defect) are present that could indicate a syndrome with cleft palate. Additionally, 3D surface rendering ultrasound can generate a facial image that is helpful for parental counseling – seeing a 3D image of the baby's cleft can prepare the family and facilitate discussions with surgeons. Overall, ultrasound is the frontline screening tool, with fetal MRI/3D US reserved for further characterization in select cases.

Parental Counseling and Psychological Support: A prenatal diagnosis of CLP can be emotionally challenging for expectant parents. It is essential to provide compassionate, clear counseling once a cleft is identified. Ideally, the family should meet with a cleft/craniofacial team (or at least a pediatric surgeon or genetic counselor) before birth.[10,11] Key aspects of prenatal counseling include:

- **Information about the Condition:** Explain in simple terms what a cleft lip and/or palate is, and the range of severity. Parents should understand that this is a treatable condition – the infant will need surgeries in infancy and childhood, but outcomes for appearance, feeding, and speech are generally very good. Showing photos of treated children or diagrams can help set expectations. Emphasize that the baby's brain development is not affected, and the child should lead a normal life with proper care.
- **Feeding Plan:** One of the immediate concerns is how the baby will feed. During prenatal visits, the team (often a specialized nurse or feeding specialist) can teach parents feeding techniques for cleft babies.[5,12] As an example, they will be introduced to special squeeze bottles or nipples designed for cleft palate (more on these in the next section). Being prepared in advance significantly reduces anxiety – parents who have received feeding instruction are more confident and less likely to have their infant require NICU admission solely for feeding issues. If possible, a demonstration with a model or video on using cleft feeding bottles is done.
- **Treatment Roadmap:** The multidisciplinary team should outline the treatment timeline that the child will undergo. Parents are informed that

the lip repair will be done around 3–6 months of age, the palate repair around 9–12 months, followed by other interventions (speech therapy, dental work, later surgeries) as the child grows (this will be detailed in a later section). Providing this roadmap helps parents mentally prepare for the journey. Written materials or pamphlets can reinforce this information.

- **Associated Anomalies & Genetics:** Families should be offered a consultation with a genetic counselor or medical geneticist, especially if the cleft was detected alongside other ultrasound findings. The counselor will review family history and the possibility of a syndrome. Sometimes, additional testing may be suggested: for example, an amniocentesis or non-invasive prenatal testing for chromosomal abnormalities, or a targeted microdeletion test if a syndromic cause is suspected (e.g., testing for 22q11 deletion if a cleft palate and cardiac defect are seen). If the cleft appears isolated and there are no other risk factors, invasive testing might not be needed, but it's still useful to discuss recurrence risk in future pregnancies (usually ~4% for an isolated cleft if no family history, higher if familial) and the multifactorial nature.
- **Emotional Support:** Discovering a birth defect can lead to guilt, anxiety, or sadness. It's important to reassure parents that *nothing they did or did not do* definitively caused the cleft in most cases – e.g., clefts often happen despite best efforts, and sometimes even with no obvious risk factors. Psychosocial support resources should be provided. Many regions have parent support groups or organizations (for instance, in India and globally, groups of parents of children with clefts, or NGOs). Connecting expectant parents with another family who has been through the process can provide hope and practical advice. In counseling, acknowledging the emotional impact and encouraging parents to ask questions is key.
- **Delivery Planning:** Generally, a baby with an isolated cleft does not require delivery at a very high-level center; a normal maternity hospital with pediatric support is sufficient. However, if a Pierre Robin sequence (PRS) is suspected (which can cause airway obstruction at birth), arrangements should be made for delivery where skilled neonatologists and possibly a NICU are available. The team will discuss that at delivery, the neonatal staff should be aware of the cleft diagnosis so that immediate steps (like ensuring a good airway and feeding plan) are taken. Most cleft teams encourage the mother to attempt breastfeeding at birth if it's a cleft lip only, or to start alternative feeding methods soon after birth for cleft palate. A plan for follow-up shortly after birth (often the cleft team will see the baby within the first week or two) is arranged.

PERINATAL AND NEONATAL MANAGEMENT

Once the baby with CLP is born, attention shifts to addressing immediate needs and laying the groundwork for successful early care. Perinatal management involves ensuring a safe airway, enabling adequate feeding for growth, screening for any other anomalies, and supporting the parents in these early days.

Immediate Postnatal Care

***Airway and Breathing*:** Immediately at delivery, the infant's airway should be assessed, especially if a cleft palate is present. Most babies with cleft lip and/or palate breathe normally, but a subset can have airway obstruction. This is of particular concern in Pierre Robin Sequence (PRS) – infants with PRS have a small recessed jaw (micrognathia) and a tongue that falls back, often leading to breathing difficulty when supine. They also typically have a U-shaped cleft palate. In the delivery room, if an infant is noted to have signs of PRS (small chin and cleft palate), special care is needed: *Neonatal resuscitation protocols* should anticipate a possibly difficult airway. These babies may experience significant upper airway obstruction due to the tongue occluding the pharynx.[13] Initial steps include positioning the baby prone (on the stomach) or side-lying, which helps the tongue fall forward and open the airway. A skilled neonatologist or anesthesiologist may be needed to secure the airway if mask ventilation is ineffective – intubation can be challenging due to the jaw anatomy, so having tools like a video laryngoscope or even a neonatal nasopharyngeal airway can be life-saving.[13]

Fortunately, only a small percentage of cleft palate babies (those with severe PRS) need invasive airway support. For the majority of CLP newborns, routine care with attention to keeping the nasal passages clear is sufficient. Babies with cleft lip alone generally have no airway compromise at all. It is prudent to have neonatal personnel aware of the cleft diagnosis at birth so they can suction gently if needed and avoid nasal trauma (since cleft babies may have a deviated septum or smaller nasal passages on the cleft side). If breathing is labored even after positioning, supplemental oxygen or an oropharyngeal airway may be used. In rare cases, PRS infants who cannot maintain saturation might need a temporary nasopharyngeal tube or intubation. Thus, anticipation and preparation are key – for example, delivering a known PRS case at a center with NICU, and having an otolaryngologist or pediatric anesthesiologist on standby for advanced airway management.

***Circulation and Apgar*:** Apart from the airway, standard newborn care applies. The presence of a cleft does not typically affect heart rate or initial circulation, unless there are hidden internal malformations. The baby's Apgar scores are usually normal except in cases with airway obstruction. Once stabilized, the baby should undergo a thorough physical examination.

***Initial Examination and Anomaly Check*:** A neonatologist or pediatrician should perform a detailed exam in the first hours after birth. Besides confirming the cleft lip and/or palate and its extent, the examiner should look for any associated anomalies:

- **Oral exam:** Determine if the cleft palate is present (and if it's hard and soft palate, or soft only). Sometimes a submucous cleft might be subtle. Check for **lip pits** on the lower lip (which suggest Van der Woude syndrome). Examine the jaw size (micrognathia), tongue placement, and any signs of airway obstruction.
- **Facial structure:** Evaluate the eyes (for coloboma or other defects), palpate the skull (craniosynostosis syndromes may have cleft and fused sutures), and assess nasal deformities.
- **Hands/feet:** Look for syndactyly or polydactyly, which could indicate a syndrome (e.g. cleft lip can be part of EEC syndrome which includes ectrodactyly). Clubfoot or limb anomalies might suggest an amniotic band sequence if a cleft is also present.
- **Cardiac exam:** Carefully listen for heart murmurs. Congenital heart defects can co-occur with clefts, particularly in syndromes like 22q11.2 deletion (which often has conotruncal heart defects and cleft palate). If any murmur or abnormal pulses are noted, a pediatric cardiology consult and an echocardiogram are warranted. Routine screening echo is not mandatory for an isolated cleft if exam is normal, but a low threshold for cardiac evaluation is advised if any suspicion.
- **Abdominal/urogenital:** Check for abdominal wall defects (unlikely in isolated CLP but part of certain syndromes) and palpate kidneys if possible. Some syndromes with cleft (like charge syndrome) can have renal anomalies. Consider a screening renal ultrasound if multiple anomalies exist. Examine the genitalia for any ambiguity (rarely, midline defects can co-occur).
- **Neurologic:** Assess tone and look for spine defects (e.g. a sacral dimple might point to underlying spinal issues). While clefts alone don't cause neurologic issues, they can be one feature of broader syndromes that involve the CNS. If the baby has a cleft palate and other midline issues (like holoprosencephaly sequence), neurologic exam might show abnormalities. In summary, the newborn exam aims to distinguish an isolated cleft from a potentially syndromic cleft that has other congenital anomalies. Approximately 25–50% of infants with cleft palate (especially females with cleft palate only) have additional malformations[14] so a meticulous exam is justified. If multiple anomalies are present, a genetics consult is indicated in the neonatal period for further workup.

***Neonatal Resuscitation in Pierre Robin sequence (PRS)*:** These babies often require immediate intervention to establish ventilation. Simple measures like the prone position often suffice to relieve obstruction. If not, insertion of a nasopharyngeal airway (a soft tube placed through the nose to the throat) can bypass the tongue base obstruction. The neonatal team should be ready with intubation equipment, though

intubation should be done by the most experienced provider due to the anatomical challenge. In extreme cases where intubation fails, a neonatal ENT surgeon might need to do a quick procedure (like tongue-lip adhesion or even tracheostomy) – however, this is exceedingly rare at birth and more often a later consideration if conservative measures fail. The majority of babies with clefts do not have PRS and will breathe normally; thus routine care (warmth, clearing airway, stimulation as needed) is usually adequate. Awareness and preparedness ensure that those few who do have critical airway issues are promptly managed, preventing hypoxia.

FEEDING CHALLENGES AND SOLUTIONS

Feeding is the foremost challenge in the neonatal period for an infant with cleft lip/palate. A newborn must feed effectively to grow, but a cleft, especially of the palate, disrupts the normal mechanics of sucking. Normally, a baby creates suction by sealing the lips around the nipple and closing off the nasal cavity with an intact palate while tongue and jaw motions draw milk out. In a cleft palate, there is an opening between the mouth and nose, so the baby cannot generate negative pressure suction – it's like trying to drink through a straw with a hole in it. Key feeding issues include: difficulty latching onto breast or standard bottle, insufficient suction leading to prolonged feeding times, nasal regurgitation of milk (milk coming out through the nose due to the open palate), choking or gagging episodes, and the baby tiring out before taking enough volume. Cleft lip (without palate) can also make it hard to latch, especially if the cleft is wide or bilateral, but many infants with cleft lip alone *can* breastfeed or feed with minimal help.

The bigger problem is cleft palate. To address these challenges, specialized feeding techniques and devices are used:

- **Positioning:** Feeding the baby in a more upright position (nearly sitting) helps reduce milk entering the nasal cavity and uses gravity to assist swallowing. This also can prevent choking and aspiration. Caregivers are taught to keep the baby's head higher than the stomach during feeds and slightly tilt the bottle to always keep the nipple filled with milk (to minimize air swallowing).
- **Special Bottles and Nipples:** A variety of specialized feeding bottles have been designed for cleft-affected infants. These allow milk to flow with minimal suction effort:
  - The **Mead Johnson Cleft Palate Nurser** is a soft, squeezable plastic bottle with a cross-cut nipple. The caregiver can gently squeeze the bottle in rhythm with the baby's sucking to deliver milk, essentially substituting for the baby's suction pressure.[15] It's a simple and low-cost system widely used in many centers (including India).
  - The **Medela SpecialNeeds Feeder (formerly Haberman feeder)** is a one-way valve bottle system. It has a special nipple with a valve that fills with milk and only releases it when the baby compresses the nipple (not by suction but by gumming it). The flow rate can be adjusted by rotating the nipple to different markings. This feeder allows very efficient feeding for babies who have difficulty generating any suction – a slight bite and compress will push milk out.
  - The **Pigeon Cleft Palate bottle** has a Y-cut nipple and a one-way valve that prevents air ingress. The nipple is extra-long and firm on top but soft on the underside, so when the baby's tongue moves, it squeezes milk out. A similar principle is used in Dr. Brown's Specialty Feeding System.
  - Traditional squeezable bottles with enlarged nipple holes or cross-cuts are also common. For instance, some practitioners in India simply use a regular disposable plastic bottle that is soft and cut a larger X in a standard nipple – though care must be taken to control flow. According to a national survey, spoon feeding or cup feeding is also very popular in India for cleft infants: about 90% of Indian surgeons advise using a spoon or indigenous cup (paladai) to feed initially.[16] A paladai is a small cup with a spout (elongated snout cup) traditionally used to feed infants; caregivers can drip milk into the baby's mouth in small sips. This method avoids the need for sucking altogether. Indian studies found many families

use such techniques (one survey noted *paaladai* use in 65% of cases in South India). The advantage is simplicity and availability; the drawback is it can be slow and requires practice to avoid aspiration.

- **Breastfeeding *vs.* Expressed Milk:** Direct breastfeeding is often extremely challenging for babies with a cleft palate. Even though breast milk is ideal, the baby usually cannot latch and suck efficiently due to the cleft. Mothers are encouraged to pump and then feed breast milk via the specialized bottle. Breast milk provides added benefits (e.g. lower risk of ear infections which CLP babies are prone to) . Some mothers with only cleft lip babies (no cleft in palate) can successfully breastfeed by occluding the cleft lip area with their breast tissue or a finger. If breastfeeding is attempted, the mother may need to try different positions (e.g. the "football hold" to get a better seal). However, for cleft palate, the consensus is to use alternative feeding methods. It's important to reassure mothers that using a bottle in this scenario is not a failure – it is a necessity to ensure the baby gets enough nutrition. The focus should be on giving breast milk by alternative means if direct nursing isn't possible. In some cases, a combination approach is used: breastfeed for comfort/bonding if the baby can get a little milk, but supplement each feed with expressed milk via a cleft bottle to ensure adequate intake.
- **Feeding Techniques:** Caregivers are taught techniques like paced feeding – allowing the baby to pause often, since cleft infants may gulp air or tire. They are advised to watch for cues of stress (e.g. the baby stops sucking or starts coughing) and to pause, let the baby burp, then resume. Because cleft babies may take in more air, frequent burping (after every ~5–10 minutes or half-ounce) is recommended. If milk comes out the nose, one should pause and let the baby clear it (suction gently if needed, though often the baby will sneeze or expel it). Keeping a bulb syringe handy can help clear nasal regurgitations.
- **Feeding Obturators:** In some centers, a temporary feeding obturator (palatal plate) is made by a pediatric dentist soon after birth. This is essentially a custom acrylic plate that covers the cleft in the palate, snapping into the roof of the mouth, to restore separation between the oral and nasal cavity during feeding. The idea is to provide a surface against which the baby can press the nipple and create suction. However, evidence on feeding obturators is mixed – a Cochrane review found no significant improvement in growth with use of a plate versus not.[17] Many teams forego obturators due to cost and the need for frequent refitting as the infant grows. Instead, they rely on the specialized bottles which have largely made obturators less critical. That said, if a family has access to a cleft orthodontist early, nasoalveolar molding (NAM) appliances can be started in the neonatal period. NAM's primary goal is to mold the gums and nose prior to surgery, but it also doubles as a plate that covers the cleft. In India, some tertiary centers initiate NAM within the first few weeks of life to reduce the gap for eventual lip repair. This requires the family to adhere to weekly adjustments. While NAM can improve the surgical outcome, its role in *feeding* is supplemental – babies with NAM still usually use squeeze bottles to feed, though the plate may help a bit with suction.
- **Monitoring and Weight Checks:** Because feeding is harder, these infants are at risk for poor weight gain. It's important to closely monitor their weight. The pediatrician will likely have the baby come for weight checks in the first week or two to ensure they are back to birth weight by 2 weeks. If the baby is failing to gain adequately, adjustments need to be made – e.g., higher calorie formula or fortifying expressed breast milk, more frequent feeds, or in rare cases feeding via a temporary nasogastric tube if oral feeding is truly inadequate. Most babies, once the right bottle and technique are found, will feed well enough by mouth. Parents should be encouraged that feeding will get easier with practice and as the baby grows.
- **Avoiding Aspiration:** Caregivers are taught to be vigilant about not squeezing too much milk too fast. The baby should be relatively awake and in a semi-upright posture to coordinate swallowing. If recurrent coughing or choking occurs,

consultation with a feeding specialist or speech therapist can help adjust technique. Sometimes using a slow-flow nipple and gradually increasing flow as tolerated is necessary. The motto is "fed is best" – whichever method results in a content, growing baby is the right method.

- **Transition to Cup Feeding Pre-surgery:** By around 5–6 months of age (for those with cleft palate), many surgeons in India advise transitioning the infant from bottle to cup feeding prior to palate repair. This is because after palate surgery (which often happens around 9–12 months), sucking on a hard nipple or bottle may risk damaging the repair. Teaching the baby to drink from a cup or spoon by 6–7 months can make the post-operative feeding easier (since they can then use a cup while the palate is healing). Thus, some cleft teams have a protocol to start introducing a trainer cup at around mid-infancy.

In summary, feeding a baby with CLP requires patience and adaptation. With the use of specialized feeders like Haberman or squeezable bottles, most babies can take adequate nutrition orally and thrive. In India, where access to expensive feeders might be limited in rural areas, simple measures such as paladai feeding or modified bottles are effectively used. A study noted that spoon/cup feeding was recommended by over 90% of Indian cleft surgeons, reflecting cultural preferences and resource considerations.[16] Regardless of method, the primary goals are to ensure the baby is safe during feeds, gaining weight, and that the parents feel confident. Early involvement of a feeding specialist (often a speech-language pathologist with expertise in feeding) can be very beneficial. This specialist can continue to follow the child for feeding and later speech development.

Associated Anomalies and Syndromic Workup

As discussed, a portion of infants with clefts will have other anomalies or be part of a syndrome. Recognizing this early allows appropriate referrals and workup. After the initial exam, if any red flags for syndromes are present, the neonatologist should coordinate further evaluations:

- If a heart murmur is noted, a pediatric cardiologist consult for echocardiography is indicated (even if the cleft seems isolated, a significant murmur warrants investigation as heart defects are common concomitants). For example, cleft palate plus conotruncal heart defect might suggest 22q11 deletion – in such a case, genetic testing for DiGeorge syndrome should be done.
- For multiple anomalies, a full genetic evaluation is advised. This may include chromosome analysis or microarray, and specific gene tests if certain syndromes are suspected. A genetics team will also examine the baby dysmorphologically (face shape, eye distance, limb patterns, etc.) to look for syndromic diagnoses. In India, where advanced genetic testing may not be universally available, at least a clinical genetics exam is valuable. They might recommend sending blood for karyotype or targeted tests to reference labs if needed.
- **Hearing tests:** Newborn hearing screening (otoacoustic emissions or auditory brainstem response) should be done as per routine for all newborns. Babies with cleft palate are at high risk for otitis media with effusion (glue ear) because the eustachian tube muscles are affected. Many will develop middle ear fluid and conductive hearing loss in infancy. While a hearing screen at birth might still be passed, it's important to plan follow-up hearing assessments. Typically, an ENT specialist will monitor ear status and often place tympanostomy tubes (grommets) at the time of palate repair to prevent persistent fluid. In the neonatal period, just ensure the initial hearing screen is done and caregivers are told about the need for audiology follow-up.
- **Ophthalmology:** If there are ocular anomalies (coloboma, etc.), involve an eye specialist. Some syndromes (like Stickler syndrome, which can present with PRS cleft palate, have retinal detachment risk and myopia) require early ophthalmologic screening.
- **Cranial ultrasound or MRI:** If the cleft is part of a suspected broader midline defect (rare, e.g. holoprosencephaly sequence with cleft lip), a cranial ultrasound or MRI might be indicated. But for an isolated cleft, neuroimaging is not routinely needed.
- **Interdisciplinary clinic:** Many cleft programs have a protocol that within the first few weeks of life, the baby will be seen by the whole cleft team.

This often includes the surgeon, pediatrician, orthodontist, speech therapist, and others all in one visit or coordinated around the same time. At this visit, any further syndromic evaluation can be planned. For example, if the baby has cleft palate and micrognathia, the team might obtain a skeletal survey or an eye exam to check for Stickler syndrome and get an ENT evaluation for airway.

It's notable that in one series, about 15% of babies with cleft lip ± palate had additional malformations and among isolated cleft palate cases the percentage with other anomalies can be higher (some sources say up to 40–50% have at least one other anomaly)[14]. Common associated anomalies include cardiac (VSD, tetralogy), craniofacial (hemifacial microsomia), neurological (Chiari malformation with syndromic clefts), and skeletal (vertebral anomalies as in Klippel-Feil). Each of these requires specialist involvement. A structured approach is often followed, such as the VACTERL evaluation if multiple anomalies (Vertebral, Anal, Cardiac, Tracheoesophageal, Renal, Limb) – clefts are not part of VACTERL, but if a cleft baby has some VACTERL features, the rest should be checked.

Parental Guidance in Neonatal Period: Along with medical management, a significant part of perinatal care is educating and supporting the parents. In the hospital, the nursing staff and doctors should coach the parents on how to feed the baby, how to clean the cleft site (like after feeds, wiping gently any milk from the nose/lip), and how to position the baby during sleep (prone or side positioning if PRS, otherwise on back is fine for most cleft infants as per safe sleep guidelines, unless airway issues dictate otherwise). They are instructed on signs of respiratory distress or failure to feed that would necessitate prompt medical attention. Providing written instructions or references (for example, diagrams of how to use the special bottle, a list of follow-up appointments with the cleft clinic) is helpful since new parents may be overwhelmed.

Before discharge, it's ideal to schedule the first follow-up with the cleft team. Many programs see the baby at 1–2 weeks of age. In India, where travel may be an issue for families from remote areas, coordinating with local health workers to check on the baby's feeding and weight can be beneficial. Additionally, parents should be connected with any available resources – for instance, government schemes or NGOs sometimes provide free cleft bottles or cover surgery costs; knowing this can relieve financial worry.

To summarize, neonatal management of CLP centers on breathing and feeding – the two vital functions. Once those are ensured, and any other anomalies are identified for further workup, the infant is well on track. By the end of the neonatal period (first month), the goal is that the baby is gaining weight adequately with the chosen feeding method, the family is comfortable in care techniques, and plans are in place for the next steps (surgical consultations, etc.). The groundwork laid in this period sets the stage for successful surgical repair and development.

Multidisciplinary Care and Long-term Planning

Management of cleft lip and palate is a long-term endeavor that spans from birth through adolescence. A coordinated multidisciplinary cleft team is critical to address the varied needs at different stages. In India as well as globally, cleft care is typically organized through such teams at specialized centers. The core team members include:

- **Plastic/Reconstructive Surgeon (or Oral & Maxillofacial Surgeon):** Leads the surgical repair of the lip, palate, and later revisions or jaw surgeries.
- **Pediatrician:** Oversees the child's general health, nutrition, and development, and coordinates care, especially in infancy.
- **Craniofacial Orthodontist/Pediatric Dentist:** Guides dental and jaw development. They may perform pre-surgical orthopedics (like NAM), later orthodontic treatments, and coordinate alveolar bone graft timing.
- **Speech-Language Therapist:** Monitors speech and resonance. Provides therapy for articulation or nasality issues after palate repair and assesses velopharyngeal function.
- **ENT (Otolaryngologist) and Audiologist:** Manages ear health (places ventilation tubes in ears during palate surgery if needed) and hearing tests. Treats any airway issues (e.g., tonsils/adenoids, which can affect speech or breathing) and addresses nasal deformities.

- **Clinical Psychologist or Counselor:** Assists with psychosocial aspects – self-esteem, peer issues, and counseling for the family. Especially crucial during school-age and adolescence when appearance and speech differences can impact the child emotionally.
- **Cleft Nurse Coordinator:** Often acts as the point of contact, educating families, arranging appointments, and tracking the child's progress across specialties.
- **Geneticist:** In syndromic cases, helps with genetic diagnosis and counseling for the family regarding recurrence.
- **Nutritionist and Social Worker:** Sometimes involved if there are feeding/growth concerns or socioeconomic challenges in adhering to treatment. The social worker helps families access resources (in India, helping with hospital visits or financial aid for surgeries, etc.).

This team approach ensures that at each milestone of the child's growth, appropriate interventions are done. An optimal treatment protocol is often laid out as a timeline from infancy to adulthood. Below is the typical timeline of surgical and auxiliary interventions:

- **Newborn Period:** Feeding support (obturator or special bottle), possible taping or NAM (nasoalveolar molding) started in the first weeks to gradually align cleft segments and shape the nose prior to lip. Not all centers do NAM, but if done, it usually continues until lip repair.
- **Lip Repair:** Usually performed around 3 to 6 months of age. Many surgeons follow the classic "Rule of 10s" (at least 10 weeks old, weight 10 pounds, hemoglobin 10 g/dL) as a guideline for timing. In India, the majority of surgeons repair the lip before 6 months, most commonly between 3–4 months). If pre-surgical orthopedics (NAM or lip taping) were used, it often allows a better alignment and tension-free repair. Techniques for lip repair vary. The two most popular techniques are:
  - **Millard's rotation-advancement flap:** This is an "organic" repair where the surgeon creates a rotation flap of the lip to restore the Cupid's bow and an advancement flap to fill the gap. It results in a zigzag scar along natural lines. In an Indian survey, ~58% of surgeons preferred a variation of Millard's technique for unilateral cleft lip: it's also widely used worldwide.
  - **Tennison-Randall triangular flap:** Also known as a Rose-Thompson or triangular flap repair, this involves cutting small triangles to insert tissue and create a symmetric lip height. It leaves more visible scars but can achieve good form. Some surgeons use it particularly for wide clefts. For bilateral cleft lip, variations of Millard or Mulliken techniques are common, often done in one stage for both sides. If the premaxilla is extremely protruding in a bilateral case, a preliminary lip adhesion or molding plate might have been done to help retract it, but in India ~73% surgeons do *not* use lip adhesion. The primary lip repair typically also includes a primary rhinoplasty (basic shaping of the nose/nasal sill) to improve nasal symmetry, though definitive rhinoplasty is left for later. After lip repair, the baby's lip is intact, which aids feeding (breastfeeding might even be possible for some if palate is not cleft, now that lip is fixed).
- **Palate Repair (Palatoplasty):** The palate is usually repaired at 9 to 12 months of age, before the child develops significant speech. Timing is a balance: early repair (before 1 year) is better for speech acquisition, but operating too early (<9 months) might risk maxillary growth restriction. Most protocols aim for around 10–12 months. In India, about 76% of surgeons prefer to close the palate between 6–12 months, with others by 18 months. The goal is to have the palate closed by the time the child starts speaking their first words. Techniques for palatoplasty include:
  - **Intravelar veloplasty:** Reconstructing the muscles of the soft palate (like levator veli palatini) in a functional fashion to achieve proper elevation for speech. This is done in virtually all modern repairs.
  - **Two-flap palatoplasty (Von Langenbeck) with pushback:** Commonly used for hard palate – creating two mucoperiosteal flaps, freeing them (incisions along the gum edges) and then repositioning toward midline to close the defect. Often combined with a slight pushback to lengthen the palate.

- **Furlow double-opposing Z-plasty:** A technique for soft palate closure that lengthens the soft palate by Z-plasty of the muscle and mucosa, which can improve speech outcomes (reduces VPI). Some surgeons do a one-stage complete palate repair (closing both hard and soft at once). Others might do a two-stage palate repair (soft palate at ~9–12 months, then hard palate at ~18 months or older) especially if the baby's health was an issue or the cleft was very wide. The trend, however, is towards one-stage early complete repair for best speech. After palatoplasty, babies must use cup/spoon feeding (no sucking) for a few weeks and be on soft diet if older. The risk of fistula is present (~5–20% cases may get a palatal fistula that might require later repair).

- **Ear tubes:** At the time of palate surgery, the ENT often places **ventilation tubes** in the eardrums to drain fluid and prevent otitis media, since nearly all cleft palate infants have eustachian tube dysfunction. This helps improve hearing and reduces ear infection frequency.
- **Speech Therapy and VPI management:** Starting around 1 year (after palate repair), a speech therapist monitors the child's babbling and early words. By 18–24 months, if any speech delay or misarticulation is present, therapy may begin. Many cleft palate children will require speech therapy in early childhood to correct compensatory articulation (they may have learned to produce sounds in the throat). Some may develop **velopharyngeal insufficiency (VPI)**, where despite palate repair, there is excessive nasal air escape during speech (hypernasal speech). Around 20% of repaired cleft palate kids might need a secondary surgery or intervention for VPI, such as a pharyngeal flap or a sphincter pharyngoplasty, often done at ~4–6 years old if therapy alone cannot correct the resonance. This is determined by a speech evaluation and possibly a nasendoscopy around age 4 or 5 if hypernasality persists.
- **Dentition and Orthodontics:** From infancy, good oral hygiene is encouraged. The cleft gums (alveolus) means the child will have missing or malpositioned teeth in that area. A pediatric dentist should examine the teeth as they erupt (first teeth ~6–7 months). Often, early childhood caries a risk if feeding at night, etc., so preventive dental care is important. Around 5–7 years, the child will start losing baby teeth and getting adult teeth. For those with an alveolar cleft (cleft extending into the gum line), an alveolar bone graft is planned typically between 8–12 years (timed when the permanent canine tooth root is about half-2/3 formed, since the bone graft will support the erupting canine).[18] Before the bone graft, the orthodontist often uses an expander to widen the upper jaw if it is constricted (common in cleft palate cases). This maxillary expansion around 5–7 years creates room and alignment for bone grafting (). Then bone (often taken from the child's hip/iliac crest) is placed into the alveolar cleft to bridge the gap in the gum line (). This bone graft allows tooth eruption through it and provides stability for the arch. After healing, braces are usually used in mixed dentition to line up the teeth.
- **Orthodontics and Jaw Surgery:** As the child grows, regular orthodontic treatment is required in most cases to straighten teeth. Many children with clefts, particularly complete cleft lip and palate, develop a midface growth deficiency – the repaired scar tissue can restrict forward growth of the maxilla, leading to a Class III malocclusion (underbite). During later childhood (10–12 years), orthodontists will use growth modification if possible but by adolescence (14–18 years), it becomes clear if the jaw alignment is significantly off. If there is a severe maxillary retrusion causing functional or aesthetic issues, orthognathic surgery is considered after growth is complete (often ~16–18 years for females, 18–20 for males). This typically involves a Le Fort I osteotomy to advance the upper jaw, sometimes combined with a jaw expansion or mandibular surgery as needed. In some cases, distraction osteogenesis (gradually moving the bones with a device) is used for major advancements (). Orthognathic surgery dramatically improves the bite and facial profile. Planning for it involves the surgeon and orthodontist working closely (orthodontics to decompensate teeth positions pre-surgery,

then surgery, then finishing orthodontics). Not all cleft patients need this – roughly 25–50% of complete UCLP patients might – but it's an important part of long-term planning.

- **Secondary/Revision Surgeries:** Throughout childhood and teen years, additional surgeries might be needed:
  - **Lip/nose revision:** As the child grows, scarring from the lip repair might cause lip thickness asymmetry or nasal deformity (the nose on the cleft side can have a collapsed ala). Around 5–6 years or often in early teens, a revision rhinoplasty and lip revision can be done to refine appearance. Many teams wait until their faces are nearly grown (late teens) to do a definitive rhinoplasty for the nose shape. However, minor revisions (like improving the nasal tip or lengthening the columella in bilateral cleft cases) can be done earlier. The IAP guideline suggests a formal lip/nose revision (rhinoplasty) after 13–14 years (), unless there's a functional reason earlier.
  - **Palatal fistula repair:** If a fistula (opening) in the palate remains after the initial repair, a secondary operation is done usually around 4–5 years (or earlier if it causes feeding problems). Fistulas can affect speech (air leak) or cause food leakage into the nose.
  - **Velopharyngeal insufficiency surgery:** as mentioned, a pharyngeal flap or sphincteroplasty might be done around 4–6 years for persistent hypernasal speech not fixed by therapy.
  - **Bone graft (as above)** at ~9–10 years.
  - **Scar revisions:** Sometimes, small adjustments to scars on the lip or nose are done along the way if needed. And if the child has a deviated nasal septum causing breathing issues, an ENT may correct that in late adolescence (since nasal septum is important for midface growth, major septoplasty is often delayed until after growth).

This treatment timeline is individualized per patient, but it highlights that cleft care is staged appropriately to address feeding (immediate), speech (palate by 1-year, VPI by ~5 years if needed), dentition (bone graft by ~9 years), and facial skeletal issues (jaw surgery in teens). It's a long process, and thus, continuity of care is vital. Drop-outs from treatment can lead to suboptimal outcomes (e.g., an unrepaired palate beyond toddler age results in severe speech impairment; missing bone graft can lead to oronasal fistula and tooth loss). In India, ensuring follow-up can be challenging for families traveling far. This is where cleft charities often help with patient navigation and support over the years.

Speech and Hearing: After surgical repair of the anatomical defects, functional rehabilitation is crucial. Speech therapy often starts in early childhood and may continue off and on for several years depending on the child's needs. Common issues addressed include articulation (teaching the child to use the tongue and lips correctly rather than compensatory throat sounds) and resonance (reducing nasal escape, if VPI surgery was done therapy helps adapt to the new physiology). By age 5 or 6, most children with repaired clefts and appropriate therapy have intelligible speech, though some may still have slight nasal tone or require further interventions. Hearing must be monitored – with ear tubes, the incidence of hearing loss is greatly reduced. The ENT will periodically check hearing and replace tubes if they extrude until about age 6–7 when the eustachian function often improves. In case of any chronic hearing loss, hearing aids or other measures would be taken, but this is uncommon if managed well.

Dental and Orthodontic Care: Starting around age 7–8, orthodontic expansion devices might be used to correct crossbites. Later, full braces in teenage years are used to align teeth after bone graft and jaw alignment. The orthodontist is typically part of the team from early (monitoring) to late (final braces). They coordinate timing with surgeons so that, for example, they don't put braces on right before a surgery that needs them off.

Psychosocial Support and Education: As the child grows, psychological support becomes important. Young children might face stares or questions about their scar or nasal speech. Cleft teams often have psychologists who run support groups or counseling sessions. For school-age kids, speech differences or appearance differences can sometimes subject them to bullying. Equipping the child with self-confidence

and helping families and teachers educate peers can mitigate this. In India, social stigma can be an issue in some communities; educating the extended family and community that cleft is a correctable medical condition is part of the holistic care. When the child reaches adolescence, appearance concerns heighten – this is often when final cosmetic tweaks (like rhinoplasty) are done to improve facial harmony, which can significantly boost self-esteem. Throughout, involving the child in their care (as age-appropriate) and setting realistic expectations is key – the team and family work together to ensure the child's psychological development is as well tended as the physical aspects.

Follow-Up Duration: Cleft patients are typically followed through about age 18–20 (when all interventions including jaw surgery and final dental work are done). Many programs then transition them to adult care if needed (some may seek additional cosmetic improvements as adults, but that's elective). Regular team evaluations (often annually or semi-annually in childhood) track outcomes in speech, hearing, dental, and facial growth.

The multidisciplinary cleft care paradigm is essential for achieving the best functional and aesthetic results. Each specialist addresses one facet of the cleft's impact, and together they coordinate the timing, so the child isn't overburdened at any one time, and also doesn't miss critical windows (like speech development). Audit of outcomes in cleft centers has shown that centers with well-coordinated team care have superior results in speech and facial growth compared to fragmented care. For instance, a UK study found significantly higher need for secondary surgeries in patients who did not receive optimal primary treatment in a team. Thus, protocols have been developed to standardize care timelines and encourage multidisciplinary involvement, which India's cleft centers are also embracing.

FUTURE TRENDS

Cleft lip and palate management exemplifies how early diagnosis, comprehensive planning, and team-based care can transform a potentially debilitating birth defect into a treatable condition with excellent outcomes. From the very first sonogram that detects a cleft, through the neonatal feeding adaptations, to the multiple surgeries and therapies over years – a coordinated approach ensures the child can eat, speak, hear, and smile normally. Some core points include: early involvement of a cleft team (ideally even before birth) to educate and support the family; address nutrition and growth so the infant is ready for timely surgeries; performing lip repair and palate repair in infancy to optimize feeding and speech development; and providing ongoing follow-up for speech, hearing, dental occlusion, and psychosocial well-being. Family involvement is crucial at every step – parents/caregivers need to adhere to feeding techniques, attend therapy sessions, maintain oral hygiene, and keep surgical appointments. Empowering the family with knowledge and support (for example, linking with other parents of cleft children or community health workers) improves adherence to the long treatment journey.

In India, specifically, the large number of cleft births per year poses public health and healthcare delivery challenges, but initiatives in the last two decades (government health programs and NGO partnerships) have significantly improved access to care. Still, raising awareness in rural areas that clefts *can* be repaired and are not "curses" or untreatable is an ongoing need. Early referral of newborns with clefts to specialty centers can reduce infant morbidity and mortality (unrepaired clefts historically led to malnutrition-related infant deaths in some cases. Thus, training frontline health workers on immediate cleft management and feeding, and establishing referral networks, remain priorities in India's health system.

Encouraging Family Involvement: A child with CLP will require multiple hospital visits and procedures – this can be taxing for families emotionally and financially. It's important to involve the family as active participants in care. Educating them on each upcoming step demystifies the process and helps them prepare (for instance, teaching them about palate repair well before it happens, so they arrange time off work, etc.). Many cleft centers hold parental education workshops and provide counseling at key points (like before speech surgery or jaw surgery). Such engagement fosters trust and better compliance. Additionally, celebrating the child's milestones (first time eating

solid food after palate repair, first day at school communicating clearly) with the family reinforces the positive outcomes of their commitment. Family support groups can also help caregivers cope and learn from each other. Ultimately, the family's love and determination, combined with the cleft team's expertise, is what brings about the successful rehabilitation of the child.

Future Trends in Cleft Care: The field of cleft lip and palate care continues to evolve, with research and innovation aiming to improve outcomes and reduce the burden of treatment. Some promising trends include:

- **Tissue Engineering and Regenerative Medicine:** Scientists are exploring ways to use the body's own cells and bioengineered materials to repair cleft defects without the need for invasive graft harvests. For example, tissue-engineered bone substitutes for alveolar cleft repair are under investigation. Biomaterial scaffolds with osteogenic growth factors have shown potential to stimulate bone formation in the cleft gap, possibly replacing the traditional iliac crest bone graft [19]. Similarly, research into stem cell therapy (e.g., using mesenchymal stem cells) to enhance bone regeneration or even muscle regeneration in the soft palate is ongoing. [20] In the future, a cleft palate might be repaired not just by suturing tissue but by applying biological agents that encourage the tissue to grow and fuse more effectively. Cartilage tissue engineering may also improve nasal cartilage reconstruction in cleft rhinoplasty. While these are mostly in experimental or early clinical trial stages, they hold promise to make surgeries fewer or less invasive.
- **3D Printing and Surgical Planning:** The use of 3D printing technology has already impacted craniofacial surgery and will continue to grow. Patient-specific 3D models of an infant's cleft lip/palate can be printed to help surgeons plan precise repairs or to simulate outcomes with different techniques. Custom splints or plates (for NAM or for jaw surgery) can be 3D printed for better fit. In jaw surgery, computer-assisted planning and printed cutting guides are becoming common to execute complex osteotomies accurately. These technologies can reduce operating time and improve symmetry by allowing surgeons to practice and refine the surgical plan virtually beforehand.
- **Artificial Intelligence (AI) in Cleft Care:** AI and machine learning are being applied to various aspects of cleft management. For diagnosis, AI image analysis might help identify clefts on prenatal ultrasounds or assist in screening programs where radiologists are scarce. In treatment planning, AI algorithms can analyze large datasets of cleft outcomes to suggest optimal surgical protocols for a given patient. For example, machine learning models could predict which infants are at risk of velopharyngeal insufficiency after one type of palate repair and thus recommend a different approach. AI has also been studied in speech analysis – automated programs can rate the nasality or articulation in a cleft patient's speech and provide objective feedback, which might one day augment the work of speech therapists.[21] Additionally, AI is being used to develop automated systems to evaluate surgical results (e.g., assessing facial appearance from photographs to score the success of a lip repair). This can help in research and audit by standardizing outcome measures. A scoping review highlighted that most current AI applications in cleft focus on speech outcomes and treatment planning, indicating a fertile ground for further development. As datasets from cleft centers (images, surgical metrics, long-term outcomes) grow, AI can leverage this "big data" to personalize and improve care.
- **Improved Surgical Techniques and Technology:** Surgeons are continually refining techniques to minimize scarring and maximize function. For instance, refinements in muscle repair in the palate have improved speech results. The use of surgical microscopes or loupes for delicate structures, and absorbable bone plates in infant surgery (to avoid long-term foreign materials), are technical improvements. Simulation training for surgeons (using cleft simulators or virtual reality) can enhance skill, especially important in places where experience may be limited. Moreover, robotic surgery is being experimentally tried in some craniofacial procedures; it's not mainstream for cleft repair yet, but in the future, very precise robotic-assisted suturing could possibly improve consistency of repairs.

- **Outcome Tracking and Global Collaboration:** There is a trend toward establishing robust outcome registries for cleft patients. Standardized data collection on speech, growth, dental occlusion, and patient satisfaction is being done in many cleft centers. In India, efforts like the "INDIACRAN" project aim to collect multi-center data on cleft outcomes and genetic factors. Globally, initiatives like International Consortium for Health Outcomes Measurement (ICHOM) have cleft outcome sets that centers can use to compare results. This data-driven approach, combined with AI as noted, will identify which interventions yield the best long-term results. Furthermore, international collaborations (like Eurocleft, Americleft) are conducting comparative studies and even randomized trials to resolve controversies (for example, the best palate repair technique or timing). The knowledge from these will shape future guidelines.
- **Telemedicine and Outreach:** Particularly relevant to countries like India, telehealth is playing a growing role. Follow-up speech therapy or orthodontic advice can sometimes be given remotely via video calls, reducing the burden of travel for families. Smartphone apps are being developed to help parents track feeding volumes or practice speech exercises with their child, with remote input from providers. Outreach camps and mobile units equipped for dental, or speech therapy visits in rural areas are an extension of the multidisciplinary care model to the community. These trends improve access and continuity.

CONCLUSION

The management of cleft lip and palate has advanced significantly but continues to strive for even better outcomes with fewer interventions. The comprehensive approach – from perinatal management to adolescence – means these children can grow up to be indistinguishable from their peers in terms of speech and appearance, especially as techniques keep improving. The focus is not only on curing the anatomical defect but also on supporting the child's overall development and integrating them fully into society. With ongoing research in tissue engineering and AI-driven personalized care, the future holds the possibility of making the treatment course shorter and more effective. One day, we may be able to "engineer" away the cleft gap or predict the optimal treatment path with high precision for each individual child.[19] Until then, the principles of early diagnosis, skilled multidisciplinary care, family support, and diligent long-term follow-up will remain the bedrock of cleft lip and palate management – in India and around the world.

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