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Research Paper

Orthodontic and Interdisciplinary Management of Cleft Lip and Palate: A Comprehensive Review

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ABSTRACT
Cleft lip and palate (CLP) is the most common congenital craniofacial anomaly, arising from a complex interaction of genetic and environmental factors that disrupt fusion of the facial processes between the fourth and twelfth weeks of intrauterine life. Its reported incidence varies widely with geography and ethnicity, ranging from approximately 1 in 500 births among certain East Asian populations to less than 1 in 1,700 among some populations of African descent, with Indian data suggesting an overall incidence of 1:1,000 to 1:1,500 live births. Successful rehabilitation of the cleft patient is a long-term, multi-staged undertaking that begins in the neonatal period and continues until facial growth is complete, and the orthodontist is one of the few specialists involved at every stage of this continuum. This review synthesises the current understanding of the incidence, embryological basis, etiology and classification of CLP, and consolidates the orthodontic protocols applied across the neonatal, primary, mixed and permanent dentition stages, including presurgical infant orthopedics, maxillary expansion, timing of secondary alveolar bone grafting, protraction facemask therapy, and combined orthodontic-orthognathic correction of the residual skeletal deformity. Emphasis is placed on evidence-based sequencing of care within a coordinated interdisciplinary cleft team, since fragmented or poorly timed intervention is a recognised cause of relapse and compromised long-term outcomes. A clear understanding of this sequence allows the orthodontist to anticipate treatment needs, minimise the number of surgical interventions, and optimise dentofacial, functional and psychosocial outcomes for the growing cleft patient.

KEYWORDS: *Cleft lip and palate; Orthodontics; Presurgical infant orthopedics; Maxillary expansion; Alveolar bone grafting; Interdisciplinary cleft team*

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I. INTRODUCTION

A cleft is an embryological failure of fusion involving the lip, the alveolus and/or the palate, and represents the most common congenital anomaly of the head and neck region. Cleft lip with or without cleft palate (CL±P) and isolated cleft palate (CP) are now recognised as embryologically and genetically distinct entities, although both are conventionally grouped under the umbrella term “cleft lip and palate” (CLP) for clinical purposes. The deformity is never purely anatomical: children born with CLP face a cascade of functional problems that include impaired feeding and nutrition in infancy, recurrent otitis media and hearing loss, hypernasal speech

and articulation errors, disturbed maxillary growth, malocclusion, dental anomalies, and a significant psychosocial burden that extends into adulthood if rehabilitation is delayed or poorly coordinated [1,2].

Historically, management of the cleft patient was fragmented, with surgeons operating in isolation and orthodontic input sought only when malocclusion became clinically obvious in the late mixed or permanent dentition. Over the past six decades this approach has been replaced by the concept of team care, first formalised in North America and Europe and now widely adopted across major cleft centres in India. The rationale is straightforward: no single discipline can address the full spectrum of deformity produced by a cleft, and treatment decisions made by one specialist inevitably influence the options available to another. A palatal repair performed with excessive tension restricts subsequent maxillary growth; a poorly timed alveolar bone graft compromises eruption of the permanent canine; and an orthodontic expansion performed without regard for the surgical scar tissue predisposes to relapse [2,3]. Coordinated, appropriately timed intervention is therefore central to a favourable long-term outcome.

Among the members of the interdisciplinary cleft team, the orthodontist occupies a unique position because their involvement spans the entire treatment continuum, from presurgical infant orthopedics in the first weeks of life, through interceptive correction of the mixed dentition, to comprehensive fixed appliance therapy and, where indicated, combined orthodontic-orthognathic correction of residual maxillary hypoplasia in the young adult. At each of these stages the orthodontist must integrate knowledge of normal and cleft-specific craniofacial growth, the biomechanical principles of tooth movement in scarred and often deficient alveolar bone, and the sequencing requirements imposed by the surgical, speech and audiological components of care.

The purpose of this review is to consolidate, in a single reference, the current understanding of the incidence, embryological basis, etiology and classification of cleft lip and palate, and to present a structured account of the orthodontic protocols applied at each developmental stage of the cleft patient. Emphasis has been placed on presenting this information in a chronological, dentition-stage-wise framework that mirrors clinical decision-making, since it is this sequencing — more than any single technique — that determines whether a growing cleft patient reaches skeletal maturity with a stable, functional and aesthetic outcome.

II. INCIDENCE AND EPIDEMIOLOGY

The reported incidence of cleft lip and palate varies considerably between populations, and much of this variation reflects genuine racial and geographic differences rather than differences in case ascertainment alone, although the accuracy of national registries (birth-certificate recording, hospital-based reporting, or centralised speech-and-hearing institute referral, as in Denmark and Finland) undoubtedly contributes to some of the reported disparity [4].

Populations of East Asian ancestry consistently show the highest reported incidence, historically cited at approximately 1 in 373 to 1 in 500 live births in Japanese cohorts, while certain Native American populations of the Pacific Northwest and Montana have also been reported with unusually high frequencies, attributed by early investigators to a combination of endogamy, nutritional deprivation and recurrent infectious disease within isolated communities. Populations of Caucasian ancestry occupy an intermediate position, with an incidence generally quoted between 1 in 500 and 1 in 1,000 live births. Populations of African ancestry, particularly in North American cohorts, have consistently shown the lowest reported incidence; proposed (though largely unproven) explanations have included selection bias in historical populations and differential survival related to feeding difficulty in more severe phenotypes, though neither is considered a scientifically robust explanation today. Within India, hospital-based series have reported considerable regional variation, with most authors converging on an overall national estimate of roughly 1 in 1,000 to 1 in 1,500 live births [4].

Across virtually all population groups, cleft lip with cleft palate (CLP) is the single most frequent phenotype, cleft lip alone (CL) is intermediate in frequency and shows a male predominance, while isolated cleft palate (CP) is the least frequent phenotype and shows a female predominance. Unilateral clefts substantially outnumber bilateral clefts, and left-sided unilateral clefts are reported more often than right-sided clefts in most series.

Table 1 summarises representative incidence figures drawn from major population-based reports, and is intended to orient the clinician to the wide range of figures encountered in the literature rather than to serve as a definitive epidemiological statement, since methodology and case ascertainment differ substantially between the cited sources.

Table 1. Reported incidence of cleft lip and palate across selected populations

Population / region	Reported incidence	Representative source / remarks
East Asian (Japanese) populations	≈1:373 – 1:500	Highest reported incidence among major population groups
Native American (Montana / British Columbia)	1:154 – 1:276	Attributed to endogamy, malnutrition and infectious disease

Population / region	Reported incidence	Representative source / remarks
Caucasian populations (general)	1:500 – 1:1,000	Most widely cited reference range in Western literature
Chinese populations	≈1:1,000	Intermediate incidence
African-American / New World Negro populations	1:1,700 – 1:2,700	Consistently lowest reported incidence
Trinidad (mixed Negro / East Asian Indian)	1:857 (overall)	East Indian sub-group 1:500; Negro-mixed sub-group 1:1,888
India – Tata Memorial Hospital, Mumbai (1999)	1:721	Hospital-based series
India – Assam	1:721	Hospital-based series
India – Talvada, Mumbai	1:2,594	Hospital-based series
India – overall national estimate	1:1,000 – 1:1,500	Composite estimate across regional series

III. EMBRYOLOGICAL BASIS AND ETIOLOGY

A sound understanding of normal facial embryogenesis is essential to interpreting the clinical phenotype of a cleft. The face is formed between the fourth and eighth weeks of intrauterine life through the growth and fusion of five facial processes surrounding the primitive stomodeum: the single frontonasal process, the paired maxillary processes, and the paired mandibular processes. Neural crest-derived mesenchyme migrates into these processes and proliferates beneath the covering ectoderm; failure or deficiency of this mesenchymal migration, rather than a simple mechanical failure of epithelial fusion, is now regarded as the more scientifically defensible explanation for most clefts, although the classical "failure of fusion" theory of His and Dursy retains historical importance in explaining the clinical pattern of the deformity [5,6,8,9].

The primary palate — comprising the lip, the alveolus anterior to the incisive foramen, and the premaxilla — is formed by merger of the medial nasal processes (which give rise to the median palatine process) with the two maxillary processes, a process essentially complete by the end of the sixth week. Failure of this merger produces a cleft of the primary palate, which may present clinically as an isolated cleft lip, a cleft lip and alveolus, or, when combined with failure of secondary palate fusion, as complete unilateral or bilateral cleft lip and palate.

The secondary palate — comprising the hard and soft palate posterior to the incisive foramen — develops from paired palatal shelves that arise from the maxillary processes, initially oriented vertically alongside the tongue. Between the seventh and eighth weeks, coincident with descent of the tongue and growth of the mandible, the shelves elevate to a horizontal position above the tongue and progressively fuse with one another in an antero-posterior direction, and also fuse superiorly with the nasal septum. Fusion of the secondary palate is complete by approximately the twelfth week [10]. Interruption of shelf elevation, shelf growth, or shelf fusion at any point in this sequence — whether due to an intrinsic shelf deficiency or an extrinsic mechanical obstruction to elevation, such as a large tongue in Pierre Robin sequence — produces a cleft of the secondary palate that may occur in isolation or in continuity with a cleft of the primary palate.

Etiologically, non-syndromic CLP is now understood to be a multifactorial trait resulting from the interaction of multiple genes of modest individual effect with environmental exposures during the critical period of palatal development, rather than a simple Mendelian disorder [12,13]. Twin and family studies have consistently demonstrated a strong genetic component, with recurrence risk in siblings of an affected individual substantially higher than the general population risk, and genome-wide association studies have identified a number of reproducibly associated loci [19,20]. A distinct minority of cases occur as part of a recognised Mendelian syndrome or as a feature of a chromosomal anomaly [15,16], and syndromic clefting must always be excluded through careful clinical examination and, where indicated, genetic evaluation before non-syndromic recurrence-risk counselling is offered to a family.

Environmental factors implicated as contributory teratogens include maternal smoking and alcohol consumption during the first trimester, maternal anticonvulsant therapy, maternal corticosteroid use, and periconceptional folic acid deficiency, the latter observation having led to public-health recommendations for periconceptional folate supplementation as a plausible, though not definitively proven, means of reducing non-syndromic cleft incidence [21]. Maternal nutritional status, advanced maternal age, and low socioeconomic status have also been variably associated with increased risk in epidemiological studies, though the strength and consistency of these associations differ between populations.

IV. CLASSIFICATION OF CLEFT LIP AND PALATE

A clinically useful classification system must be simple enough for routine use, yet sufficiently descriptive to guide treatment planning and permit meaningful comparison of outcomes between centres. Several classification systems have been proposed since the early twentieth century, each reflecting the anatomical or embryological emphasis of its era [22].

The Davis and Ritchie classification (1922) was among the earliest systematic attempts and divided clefts into three groups based on their relationship to the alveolus, each further subdivided by laterality. Veau's classification (1931) organised clefts into four groups of increasing severity, from an isolated soft-palate cleft to a complete bilateral cleft of the lip and palate, and remains historically influential, though it does not accommodate incomplete or submucous clefts satisfactorily. Fogh-Andersen (1942) proposed a genetically oriented classification separating clefts into cleft lip with or without cleft palate, isolated cleft palate, and rare facial clefts — a distinction subsequently validated by genetic and epidemiological research and still reflected in contemporary classification systems [17].

The classification proposed by Kernahan and Stark (1958), subsequently adopted with modification by the American Cleft Palate Association, introduced the fundamental embryological distinction between the primary palate (structures anterior to the incisive foramen) and the secondary palate (hard and soft palate posterior to the incisive foramen), and remains the conceptual basis for most modern classification systems. Kernahan's later diagrammatic "striped Y" classification (1971) represented this scheme visually as a Y-shaped figure, the two upper limbs corresponding to the right and left primary palate and the vertical limb corresponding to the secondary palate, each compartment of the Y being shaded to denote the presence, laterality and completeness of clefting at that site — a format that permits rapid, unambiguous recording of even complex or asymmetric clefts, and is reproduced schematically in Figure 1.

The LAHSHAL classification (Kriens, 1987) is an alphanumeric adaptation of the same embryological principle, in which the letters L-A-H-S-H-A-L denote, from right to left, the right lip, right alveolus, right hard palate, soft palate (the midline axis of symmetry), left hard palate, left alveolus and left lip; upper-case letters denote a complete cleft and lower-case letters an incomplete cleft at that site, allowing the entire cleft to be recorded as a compact code. This system, along with its modifications, is now among the most widely used shorthand notations for clinical documentation and audit in major cleft centres.

Additional systems of note include the Schuchardt and Pfeifer symbolic classification, which uses a set of standardised symbols superimposed on a simplified palatal outline. For everyday clinical and surgical communication, most centres continue to describe a cleft in descriptive terms — laterality, completeness, and the structures involved — supplemented by one of the coded systems above for research documentation. A comparative summary of the major classification systems is presented in Table 2.

Table 2. Comparative summary of major classification systems for cleft lip and palate

Classification system	Year	Basis / key feature
Davis & Ritchie	1922	Three groups by relation to alveolus: pre-alveolar, post-alveolar, alveolar; each subdivided by laterality
Veau	1931	Four groups of increasing severity, from isolated soft-palate cleft (Group I) to complete bilateral CLP (Group IV)
Fogh-Andersen	1942	Genetically oriented: CL±P, isolated CP, and rare facial clefts – distinct etiological groups
Kernahan & Stark (ACPA-adopted)	1958	Embryological division into primary palate (lip, alveolus) and secondary palate (hard + soft palate)
Kernahan's striped 'Y'	1971	Diagrammatic Y-shaped chart; each of 9 compartments shaded to record site, laterality and completeness (Fig. 1)
LAHSHAL (Kriens)	1987	Seven-letter alphanumeric code (Lip-Alveolus-Hard palate-Soft palate-Hard palate-Alveolus-Lip); upper case = complete, lower case = incomplete
Schuchardt & Pfeifer symbolic system	—	Standardised symbols superimposed on a simplified palatal outline

Figure 1. Schematic representation of the Kernahan striped 'Y' classification of cleft lip and palate

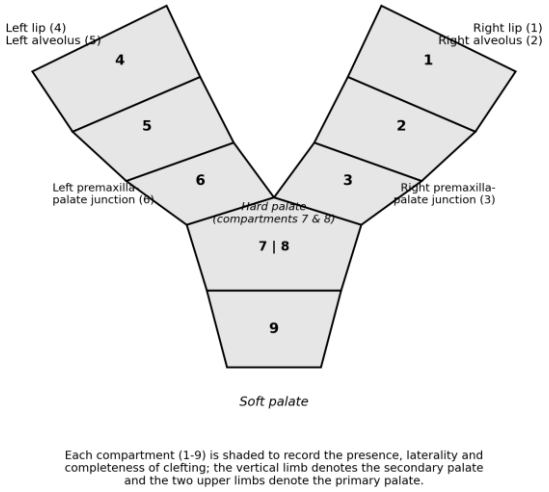

Figure 1. Schematic representation of the Kernahan striped 'Y' classification of cleft lip and palate

V. THE INTERDISCIPLINARY CLEFT TEAM AND SEQUENCE OF CARE

Contemporary cleft care is delivered by a coordinated interdisciplinary team whose core membership typically includes a plastic/craniofacial surgeon, an orthodontist, a pedodontist, an oral and maxillofacial surgeon, a speech-language pathologist, an otolaryngologist/audiologist, a clinical geneticist, a psychologist or social worker, and a dedicated clinical coordinator who manages appointment sequencing and family communication [23,24]. The clinical coordinator's role, often underappreciated, is central to the success of the team, since the family of a newborn with a cleft is typically anxious, may face significant geographic and financial barriers to repeated specialist visits, and benefits enormously from a single point of contact who can explain the overall treatment roadmap at the initial intake appointment and reinforce it at each subsequent stage.

The orthodontist's contribution begins within days to weeks of birth, when presurgical infant orthopedics may be indicated to guide the displaced alveolar segments prior to primary lip repair, and continues, without a genuine “gap” in involvement, through interceptive treatment in the mixed dentition, coordination of the timing of secondary alveolar bone grafting with the oral and maxillofacial surgeon, comprehensive fixed appliance therapy in the permanent dentition, and, in a substantial proportion of patients with more severe maxillary hypoplasia, presurgical orthodontic decompensation preceding orthognathic correction in late adolescence or early adulthood [25]. This continuum of orthodontic involvement, synchronised with the surgical and speech milestones of the team, is summarised diagrammatically in Figure 2, which presents an age/dentition-stage-wise roadmap of interdisciplinary cleft management from birth to skeletal maturity.

Figure 2. Age/dentition-stage-wise roadmap of interdisciplinary orthodontic management of the cleft lip and palate patient

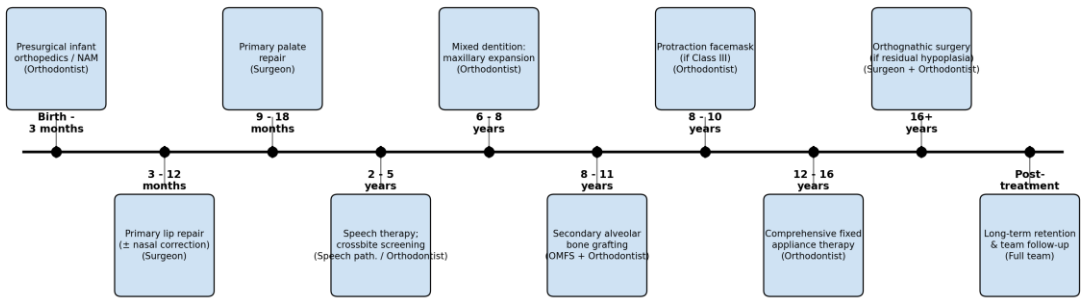

Figure 2. Age/dentition-stage-wise roadmap of interdisciplinary orthodontic management of the cleft lip and palate patient

Deviation from this sequence — for example, undertaking maxillary expansion without regard to a planned bone graft, or delaying assessment for a graft until after the permanent canine has already begun ectopic eruption — is a recognised and largely avoidable cause of compromised outcome, and underscores why familiarity with the overall roadmap, rather than isolated technical competence in any single procedure, is the defining skill of the cleft orthodontist.

VI. PRESURGICAL INFANT ORTHOPEDICS

Presurgical infant orthopedics (PSIO), also termed neonatal maxillary orthopedics, refers to the use of an intraoral appliance, with or without extraoral taping or strapping, in the first weeks to months of life to reposition the displaced maxillary alveolar segments and, in more contemporary protocols, to mould the nasal cartilages and lengthen a deficient columella before primary lip repair. The underlying rationale is that the collagen of the newborn nasal septal cartilage remains responsive to sustained moulding forces for only a brief postnatal window (attributed to circulating maternal estrogen), and that segments approximated preoperatively allow the surgeon to perform a tension-free lip repair, which in turn is believed to favour more normal subsequent facial growth, improved nasal symmetry, and easier feeding.

PSIO protocols are broadly grouped as passive or active. Passive appliances, exemplified by the Hotz plate used in the long-established Zurich protocol, are acrylic palatal plates that are periodically adjusted by selective grinding to passively guide alveolar segments toward normal alignment as the infant feeds and grows, functioning simultaneously as a feeding obturator [33]. Active appliances apply a controlled, directional force to the segments through an external mechanical framework; the Latham appliance, secured with fixation pins to the palatal shelves under brief general anaesthesia, is the prototypical active device, historically used to retract a protrusive premaxilla in bilateral clefts and to approximate the alveolar segments in unilateral clefts prior to gingivoperiosteoplasty [32,35].

A distinct and now widely practised contemporary approach is nasoalveolar moulding (NAM), popularised by Grayson and Cutting, which extends the principle of PSIO beyond the alveolus to include active moulding of the nasal cartilages and, in bilateral clefts, non-surgical lengthening of a deficient columella using a nasal stent attached to the intraoral plate, taped in place and adjusted weekly; this approach has been associated with improved nasal symmetry and, in some centres, has allowed primary columella lengthening to be deferred or avoided altogether [36,39]. A muscle-activated modification of the maxillary plate has also been described, in which the appliance is designed to harness the infant's own perioral muscle activity during feeding to assist alveolar moulding, reducing reliance on rigid mechanical force alone [38].

The Zurich concept, developed by Hotz and Gnoinski, represents one of the most extensively documented long-term PSIO protocols and combines a passive Hotz plate with a carefully staged surgical sequence intended to minimise interference with maxillary growth [33]. The Netherlands approach, in contrast, places comparatively less emphasis on PSIO for unilateral clefts, reserving active appliance therapy predominantly for cases with significant premaxillary protrusion in bilateral clefts, reflecting a persistent lack of international consensus on the indications for, and long-term growth benefit of, presurgical orthopedics — a controversy that has continued since the original scepticism voiced by several major cleft centres, and remains only partially resolved by subsequent controlled evidence, most of which has failed to demonstrate a definitive long-term skeletal growth advantage for PSIO despite its clear short-term benefits for feeding, nasal form and surgical convenience.

Regardless of the specific protocol selected, published outcome data broadly agree that PSIO does not appear to compromise long-term facial growth when performed by an experienced team, and that its principal, reproducible benefits lie in improved feeding efficiency, simplified primary lip and nasal repair, and improved nasal symmetry, rather than in any consistently demonstrated long-term skeletal growth advantage. A comparative summary of the principal PSIO protocols is presented in Table 3.

Table 3. Comparative summary of principal presurgical infant orthopedic (PSIO) protocols

Protocol / appliance	Type	Key features
Hotz plate (Zurich concept)	Passive	Acrylic palatal plate, periodically ground and adjusted; doubles as feeding obturator; combined with delayed hard-palate closure
Latham appliance	Active	Pin-retained mechanical device; retracts protrusive premaxilla in bilateral clefts / approximates segments before gingivoperiosteoplasty; placed under brief general anaesthesia
Nasoalveolar moulding (NAM – Grayson & Cutting)	Active	Intraoral plate with attached nasal stent; weekly adjustment; moulds alveolar segments and nasal cartilage; may allow columella lengthening without primary surgery
Muscle-activated maxillary appliance	Active/adaptive	Harnesses infant's own perioral muscle activity during feeding to assist alveolar moulding

Protocol / appliance	Type	Key features
Netherlands approach	Selective	PSIO largely reserved for bilateral clefts with marked premaxillary protrusion; minimal use in unilateral clefts

VII. ORTHODONTIC MANAGEMENT IN THE PRIMARY DENTITION

Once primary surgical repair of the lip and palate has been completed, typically by 12–18 months of age, the orthodontist's role during the primary dentition is largely one of surveillance rather than active intervention. Regular review, coordinated with the pedodontic and speech-language members of the team, allows early identification of the anterior and posterior crossbites that frequently emerge as the repaired maxilla grows, restrained by scar tissue from the palatal repair, relative to the unoperated mandible.

Anterior crossbite affecting one or two primary incisors, when associated with a functional mandibular shift on closure, is generally treated promptly to prevent the shift from becoming a habitual postural pattern that could bias subsequent mandibular growth; treatment options at this stage are necessarily simple, given the limited cooperation of a very young child, and are typically limited to composite build-ups of the maxillary incisal edges or a simple removable appliance where cooperation permits. Posterior crossbite, most often unilateral and associated with a functional shift, is common in the repaired cleft maxilla because of the combined effects of surgical scarring and the intrinsic growth deficiency of the cleft segment, and is generally managed with a simple removable or banded expansion appliance once sufficient primary molar support is available [44]. Both interventions in the primary dentition are deliberately conservative, and definitive, larger-scale skeletal correction is deferred to the mixed and permanent dentition stages, when growth prediction is more reliable and patient cooperation is substantially improved.

VIII. ORTHODONTIC MANAGEMENT IN THE MIXED DENTITION

The mixed dentition is the period of greatest orthodontic activity in the cleft patient, and encompasses three closely inter-related objectives: correction of the collapsed or crossbitten maxillary arch, coordination of the timing of secondary alveolar bone grafting with orthodontic expansion, and, where indicated, early orthopedic correction of an emerging Class III skeletal pattern using a protraction facemask.

Maxillary expansion

The scarred, growth-restricted cleft maxilla very commonly presents with a collapsed, V-shaped arch and a posterior crossbite that, if not corrected before the permanent canine and lateral incisor erupt, restricts the space available for these teeth and complicates subsequent alveolar bone grafting. A wide range of expansion appliances has been described for this purpose, and the choice is dictated principally by the age of the child, the number of segments requiring simultaneous movement (two segments in a unilateral cleft; three segments in a bilateral cleft), and whether slow or rapid expansion is desired. The quad-helix and bonded or banded rapid palatal expansion (RPE) appliances remain the most widely used devices [54]; slow expansion using a spring-loaded device such as the spring-jet appliance, or gentler multi-banded devices such as the butterfly expander, are preferred by some clinicians in the cleft population on the theoretical basis that slower, more physiological forces are better tolerated by the compromised periodontium adjacent to the cleft margin [47,48]. Modified Hyrax designs incorporating differential screw activation have been described for cases with inclined abutment teeth, and nickel-titanium palatal expanders, which deliver a continuous light force over an extended period, have also been advocated as an alternative to the intermittent heavier forces of a conventional screw-activated appliance [51,52]. Irrespective of the specific appliance selected, expansion in the cleft maxilla should generally be planned to produce a modest degree of overcorrection, since some relapse toward the collapsed pre-treatment arch form is almost universally observed once active expansion is discontinued, particularly across the grafted or ungrafted alveolar cleft site itself.

Timing of secondary alveolar bone grafting

Secondary alveolar bone grafting, most commonly performed using cancellous bone harvested from the anterior iliac crest, is now firmly established as an integral component of mixed-dentition management, restoring bony continuity across the alveolar cleft to support eruption of the permanent canine (and lateral incisor, when present) through grafted bone, to provide periodontal support for the teeth adjacent to the cleft, to close any residual oronasal fistula, and to provide a stable bony base for the alar cartilage. The timing of grafting relative to dental development is the single most important determinant of a favourable outcome, and the now widely accepted principle, established through the work of Bergland, Boyne, Ross and others, is that grafting should be performed when the root of the permanent canine is approximately one-half to two-thirds formed and prior to its eruption through the alveolar crest — corresponding, in most patients, to a chronological age of approximately 8 to 11 years — since bone grafted at this stage provides the most reliable substrate for spontaneous or orthodontically assisted eruption of the canine through the graft, whereas grafting performed too early or too late

is associated with reduced graft success and inferior periodontal outcomes [43,55]. Necessary orthodontic expansion to correct arch collapse and align the segments is generally completed, or at least well advanced, in the weeks immediately preceding surgery, since a well-aligned arch facilitates surgical access and allows the graft to be placed across a corrected, rather than a collapsed, cleft width; expansion is typically retained with a fixed transpalatal arch or similar appliance through the perioperative period to prevent relapse before the graft has consolidated.

Protraction facemask therapy

A proportion of cleft patients, owing to the combined effects of the primary deformity and growth restriction imposed by scar tissue from lip and palate repair, develop maxillary retrusion and an emerging Class III skeletal pattern with an anterior crossbite during the mixed dentition. When diagnosed early — ideally before 10 years of age, while the circummaxillary sutures remain relatively responsive — this pattern is amenable to orthopedic correction using a reverse-pull (protraction) headgear anchored to a rigid intraoral appliance, commonly combined with simultaneous transverse expansion to disarticulate the maxillary sutures and enhance the response to protraction [39,56]. Customised facemask designs, fitted to the individual child's facial dimensions rather than relying on a stock frame, have been advocated to improve force delivery and patient comfort [55]. Reported clinical outcomes of facemask therapy in the cleft population are generally comparable to those in the non-cleft Class III population, with the important caveat that a proportion of the correction achieved is dentoalveolar rather than truly skeletal, and that relapse of the skeletal component during the pubertal growth spurt is well recognised, so that patients treated with early protraction should be counselled that a proportion may still require orthognathic surgery once growth is complete. Functional appliances designed to influence the soft-tissue and neuromuscular environment, such as the functional regulator, have also been described as an adjunct or alternative to rigid facemask protraction in selected cases [57].

A generalised age- and dentition-stage-wise sequence integrating these three components of mixed-dentition care is presented in Table 4.

Table 4. Age/dentition-stage-wise sequencing of expansion, protraction and alveolar bone grafting in the mixed dentition

Approx. age	Procedure	Clinical rationale
6 – 8 years	Maxillary expansion (quad-helix / RPE / slow-expansion device)	Corrects collapsed, crossbitten arch before permanent canine/lateral incisor eruption; slight overcorrection planned for expected relapse
8 – 10 years	Protraction facemask (if Class III pattern present)	Circummaxillary sutures still responsive; combined with expansion to disarticulate sutures and enhance protraction
8 – 11 years (canine root ½–⅔ formed)	Secondary alveolar bone grafting (iliac crest cancellous bone)	Provides bony pathway for canine eruption, periodontal support, fistula closure and alar base support; timing is the single most important predictor of graft success
Immediately pre-graft	Completion / retention of expansion	Aligned arch facilitates surgical access; fixed retainer (e.g. transpalatal arch) maintains correction through graft consolidation
Post-graft, late mixed dentition	Monitoring of canine/lateral incisor eruption through graft	Radiographic surveillance; orthodontic traction if eruption is delayed or ectopic

IX. ORTHODONTIC AND ORTHOGNATHIC MANAGEMENT IN THE PERMANENT DENTITION

By the completion of the mixed dentition, most cleft patients will have undergone maxillary expansion, secondary alveolar bone grafting, and, in a subset, early protraction facemask therapy. Comprehensive fixed appliance therapy is generally deferred until the permanent dentition is substantially established, allowing definitive alignment, space closure or space redistribution around the grafted alveolar cleft, correction of residual rotations and crossbites, and coordination of the maxillary and mandibular arches in preparation for a stable final occlusion [41].

Dental anomalies are considerably more prevalent adjacent to the cleft site than in the general population and must be anticipated during permanent-dentition treatment planning. Congenital absence of the maxillary lateral incisor on the cleft side is the most frequent finding, occurring in a substantial proportion of patients, and treatment planning must decide, on a case-by-case basis, between orthodontic space closure with mesial movement and reshaping of the canine to simulate a lateral incisor, or space opening with eventual prosthetic or implant-supported replacement — a decision influenced by the width and health of the grafted alveolar bone, the shade and morphology of the adjacent canine, the buccal segment relationship, and the patient's facial profile [46]. Microdontia, peg-shaped or malformed lateral incisors, and impaction or ectopic eruption of the canine or lateral

incisor through the grafted bone are also disproportionately common and require close radiographic monitoring, often with cone-beam computed tomography where surgical exposure and orthodontic traction of an impacted tooth is anticipated.

A significant minority of cleft patients — reported figures vary widely between centres, reflecting differences in surgical protocol, case severity and follow-up duration, but commonly cited in the range of 20 to 30 percent — develop a degree of maxillary hypoplasia in the transverse, sagittal and/or vertical dimensions that cannot be adequately corrected by growth modification alone and that becomes fully apparent only once the adolescent growth spurt is complete. These patients require combined orthodontic-orthognathic management, generally undertaken from the mid-to-late teenage years once growth has been confirmed to be essentially complete by serial cephalometric or hand-wrist radiographic assessment. Presurgical orthodontics in this group focuses on arch coordination and dental decompensation — levelling and aligning each arch independently, without attempting to camouflage the underlying skeletal discrepancy — so that the surgical movement, most often a Le Fort I maxillary advancement, with or without a concurrent mandibular procedure, can fully correct the skeletal deformity. Given the scarred, often thin and vascularly compromised soft-tissue envelope of the previously operated cleft maxilla, orthognathic surgery in this population carries a recognised risk of greater relapse than in the non-cleft orthognathic population, and distraction osteogenesis has been increasingly used as an alternative to conventional single-stage advancement in cases requiring larger magnitudes of movement, since the gradual expansion of both hard and soft tissue is believed to improve stability. Postoperative fixed appliance therapy completes fine occlusal detailing, and long-term retention, generally more prolonged and more rigorously monitored than in the non-cleft patient, is essential given the combined orthodontic and surgical relapse tendencies inherent to this population.

X. DISCUSSION

The material reviewed above illustrates a central theme in contemporary cleft care: technical proficiency in any single procedure, whether presurgical infant orthopedics, maxillary expansion, bone grafting or orthognathic surgery, is necessary but not sufficient for a favourable outcome, and must be embedded within a correctly sequenced, team-based treatment pathway if it is to translate into durable dentofacial and functional benefit for the patient. Several areas of genuine controversy persist in the literature and deserve explicit acknowledgement. First, despite more than five decades of clinical use, the long-term skeletal growth benefit of presurgical infant orthopedics remains unproven in rigorously controlled trials, even though its short-term benefits for feeding, nasal symmetry and ease of surgical repair are widely accepted; clinicians should therefore present PSIO to families as a measure with clear short-term advantages rather than as a guaranteed means of improving eventual facial growth [34,58]. Second, although the general principle of grafting during the period of one-half to two-thirds canine root formation is broadly accepted, considerable variation persists between centres regarding the precise chronological age threshold, the choice of donor site, and the sequencing of grafting relative to orthodontic expansion, reflecting the absence of large-scale, prospective, multicentre randomised evidence comparable to that available for many other areas of orthodontics [59]. Third, outcome reporting across cleft centres remains heterogeneous, complicating meaningful comparison of protocols; standardised outcome measures represent a step toward greater comparability but have not been universally adopted [3].

For the postgraduate orthodontic trainee, the practical implication of this body of evidence is that clinical decision-making in cleft care should be approached less as the application of a single “correct” technique and more as the disciplined application of well-established sequencing principles — presurgical orthopedics before lip repair, expansion before grafting, grafting before or coincident with canine eruption, growth modification before permanent-dentition mechanics, and skeletal decompensation before orthognathic correction — adapted to the individual growth trajectory, cleft severity and cooperation of each patient, within the framework of a functioning interdisciplinary team.

XI. CONCLUSION

Cleft lip and palate remains the most common craniofacial congenital anomaly encountered in clinical practice, and its successful rehabilitation depends on coordinated, appropriately timed intervention across the neonatal, primary, mixed and permanent dentition stages rather than on any single surgical or orthodontic procedure in isolation. The orthodontist's involvement spans this entire continuum — from presurgical infant orthopedics and nasoalveolar moulding in the neonate, through interceptive correction of the collapsed maxillary arch and coordinated timing of secondary alveolar bone grafting in the mixed dentition, to comprehensive fixed appliance therapy and, where necessary, combined orthodontic-orthognathic correction of residual maxillary hypoplasia in the young adult. A working knowledge of the incidence, embryological basis, classification and, most importantly, the correct developmental sequencing of these interventions equips the orthodontist to function effectively within the interdisciplinary cleft team and to optimise the dentofacial, functional and psychosocial outcomes of the growing cleft patient. Continued multicentre collaboration, standardised outcome reporting and

prospective controlled research remain necessary to resolve the areas of persisting controversy identified in this review, particularly regarding the long-term growth benefit of presurgical infant orthopedics and the optimal, evidence-based timing of secondary alveolar bone grafting.

COMPETING INTERESTS: Nil

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