Science Journal of Clinical Medicine
2016; 5(4-1): 49-58
http://www.sciencepublishinggroup.com/j/sjcm
doi: 10.11648/j.sjcm.s.2016050401.19
ISSN: 2327-2724 (Print); ISSN: 2327-2732 (Online)

Review Article

A Century of Cleft Treatment- An Orthodontic Perspective

Anurag Mahale[1, *], Vishnu Ben Latif[1], Varun Menon P.[2], Heena Shaikh[1], Ancy Koshy[1], Bhavik Patel[1], Abdul Shahariyar[1]

[1]Department of Orthodontics and Dentofacial Orthopaedics, A.J Institute of Dental Sciences, Mangalore, Karnataka, India
[2]Department of Oral and Maxillofacial Surgery, PMS College of Dental Science and Research, Thiruvananthapuram, Kerala, India

Email address
dranuragmahale@gmail.com (Mahale A.)
[*]Corresponding author

To cite this article:
Anurag Mahale, Vishnu Ben Latif, Varun Menon P., Heena Shaikh, Ancy Koshy, Bhavik Patel, Abdul Shahariyar. A Century of Cleft Treatment- An Orthodontic Perspective. *Science Journal of Clinical Medicine.* Special Issue: Clinical Conspectus on Cleft Deformities. Vol. 5, No. 4-1, 2016, pp. 49-58. doi: 10.11648/j.sjcm.s.2016050401.19

Received: March 27, 2016; **Accepted**: March 28, 2016; **Published**: May 19, 2016

Abstract: Orofacial clefting is the most common congenital deformity. Its treatment is a long drawn process with various challenges. However, successful completion of treatment is highly satisfying not just to the patient but also the team of specialists involved with it. The following article provides an overview of the evolution of cleft treatment over the past century. It briefly describes the changing views of the orthodontic specialty towards the diagnosis and treatment of this deformity over the past century. Its gradual process from the rudimentary treatment protocols of the early 20th century to the holistic approach followed currently.

Keywords: Cleft Orthodontics, Orofacial clefts, cleft advances, Cleft lip/ palate

1. Introduction

Orofacial clefting is the most common congenital deformity. It presents itself in a number of different forms with myriads of etiological factors. Over the past century, there has been a drastic change in the outlook of the orthodontic & other concerned specialties towards this deformity. This can be owed to the tremendous progress in the diagnosis, diagnostic aids, treatment planning & modalities as well as better understanding of etiologic factors. The culmination of the 'Human Genome Project' early in the 21st Century was significant in this regard [1].

Routine orthodontic therapy lasts for a period of two years and is carried out in adolescents and adults. However, the clinical management of orofacial clefts is a completely different challenge. It extends from the neonatal period with treatment of displaced alveolar segments, to management of the skeletal and dental components of the developing dentition during the deciduous dentition, through treatment of the mixed dentition in adolescence and reaching its culmination in adulthood. This treatment also involves a number of other specialists working with the patient & caregiver at different points of time. Thus, the orthodontist's role in the treatment of this deformity is significantly different from routine fixed orthodontic therapy.

The following article gives us a brief insight into the evolution and progress of cleft treatment over the past century from an Orthodontic perspective.

This brief history of cleft management from the orthodontic perspective is divided into two parts:

1.1. The First 50 Years (1915- 1965)

There were a lot of controversies over the timing and sequencing of treatment for CLP patients. The difference of opinion was not only between orthodontics and other specialties, but also existed within the specialty itself. Orthodontists were concerned that early surgical repair would negatively affect the growth of the maxilla. However, speech therapists & pathologists favored it as it would promote intelligible speech; reduce chances of ear infections and recurrent otitis media. Normal speech is central to quality of life (QOL) of such patients and very important from the patient's & caregiver's perspective. This also improved psychological well-being of these patients.

Initially, closing the palatal cleft was a challenge. The treatment of cleft palate was limited to obturators until anesthesia became available in the 19th century. Prosthodontists or orthodontists constructed obturators with a number of materials before the advent of acrylic. In 1921, Calvin Case addressed the prosthetic correction of speech in individuals with CLP with a velum obturator constructed from black vulcanite [2]. This appliance facilitated producing the phonetic components of speech, as 'normal speech' was one of the highest priority of treatment.

Surgeons continued their interest in relation with this deformity through the 1930s. Kisskaden&Tholen[3] wrote about the primary and secondary repair of the lip in which they condemned the removal of the premaxilla in 'double harelip' cases. Davis [4] reported that 80% of palatoplasty resulted in failure often with poor speech.

Primary lip repair was performed within 24 hours of birth. Brophy supported the need for contact of the cleft alveolar segments before surgical closure with his compression appliance and primary bone grafting [5]. However, Drachter [6]demonstrated "fallacy" of closing the cleft palate by forced compression of the maxillary segments. Dentists and Orthodontists rightly acknowledged these findings & completely abandoned Brophy's technique by the 1920s.

The discovery of anaesthetics in the 19th century promoted improvements in the surgical techniques. However, the discovery of antibiotics in the mid-20th century was pivotal to the control of infection and increased surgical success. The influence of newer radiologic techniques like cephalometry enhanced understanding into further aspects of this deformity. The facial growth and development of children born with orofacial clefts was subsequently studied with serial cephalograms from birth to adulthood.

In 1937, Ivy [7] reviewed the then present literature on CLP surgery and provided insights into eugenics and heredity. His findings and conclusions were highly regressive & unacceptable by today's scientific standards.

1938, Herbert Cooper founded the first clinic in the United States of America for the sole purpose of treating CLP patients[1].The American Cleft Palate Association came into being in 1943 as a means to provide a forum for disseminating information to specialists, caregivers, parents and patients. Its official publication, The Cleft Palate Journal (now known as Cleft Palate- Craniofacial Journal) was first published in 1964 [8].

The Northwestern University CLP team introduced the concept of coordinated and integrated treatment plans in a team approach around a conference table [9].At the 1953 meeting of the American Association of Orthodontists in Dallas, the theme of "an integrated service for unfortunate dentofacial cripples" focused on a team working together just 10 years after the accepted team concept was supported by the newly established ACPA in 1943. Although the concept of team management was a natural progression in the care of children with orofacial clefts, there was a proliferation of treatment modalities and a lack of reliable and valid outcome measures that resulted in acrimonious debates on which intervention was the most effective and efficient.

Bone grafting into the cleft area to achieve bone continuity of the palate in the cleft site was being proposed, but it was not accepted as a standard of clinical practice until the availability of antibiotics; before this time, infection after surgery was difficult to control, with resulting morbidity and mortality. Graber [10] described the cleft palate deformity and provided insights into management and treatment.

In the 1950s, primary bone grafting to establish continuity in the cleft alveolus was enthusiastically adopted in several centers. However, Pruzansky [11] in 1964, called attention to the lack of a rationale to support this intervention.He pointed that the cost-to-benefit of this procedure could not be justified by its results. This led to most CLP centers discarding primary bone grafting techniques. Furthermore, it has been demonstrated that bone grafting in the primary stage of repair of cleft palate may actually be disadvantageous to the child's maxillary growth pattern. In 1972, a longitudinal study confirmed the effects of early bone grafting[12]. Rosenstein[13]and Rosenstein et al.[14] introduced a new concept in the early treatment of CLP and promoted primary bone grafting, although in reality few centers adopted the procedure.

Neonatal maxillary orthopedic procedures were used to realign the maxillary segments before surgery in patients with complete clefts of the lip and palate. There were some longitudinal studies indicating that presurgical segmental realignment before the age of 2.5 years remains relatively stable and that such treatment reduces the probability of a crossbite in the early mixed dentition. Further long-term studies of the effects of presurgical orthopedics were reported in the 1950s, and the approach of Burston [15]and McNeil[16] in Britain provided the beginning of a 60-year debate. This culminated in the nasoalveolar maxillary molding technique in the 21st century; although still controversial, it has advocates throughout the world.

By the late1950s, Orthodontists were serving on teams throughout the United States and becoming more involved in providing care for this special group of patients.

Over the past century, considerable controversy has existed about the optimal timing of orthodontic & surgical interventions.

It has basically been focused around the growth of the nasomaxillary complex. Ross &Johnston [17], found that most children with unilateral CLP, orthodontic treatment before eruption of permanent dentition had no significant effect on the facial growth.

Post- World War II, the specialty of oral surgery advanced rapidly. Elective orthognathic surgery became an important part of this specialty. Also, European concept of growth modulation with functional appliances began to receiver wider acceptance. These two factors were major influences in the treatment and management of CLP over the next 50 years.

1.2. The Next 50 Years, 1965-2015

Technical advances and case presentations at professional meetings and published in peer-reviewed journals promoted the dissemination of new knowledge and techniques with lively discussions but little supporting evidence for the unsubstantiated claims of success. In 1973, the National Institute of Dental and Craniofacial Research reported a state-of-the-art assessment of treatment interventions and their outcomes that still resonates in 2015: (1) enthusiastic claims were made for a new type of therapy; (2) the procedure was widely adopted; (3) a flow of favorable clinical reports resulted; (4) little or no positive evidence developed to support the desirability of the procedure; and (5) there was a sharp drop in the number of clinical reports, again without evidence to support the change. The conclusion from the National Institute of Dental Research report was that the best age at which to begin orthodontic treatment for children with CLP is still an open issue [18].

2. Contemporary Role of the Orthodontist in the Management of Orofacial Clefts

The original cleft palate teams in the 1950s represented 3 main disciplines: surgery, speech pathology, and orthodontics. In the 21st century, these teams are more elaborate with multiple specialties [fig. 1] [19].

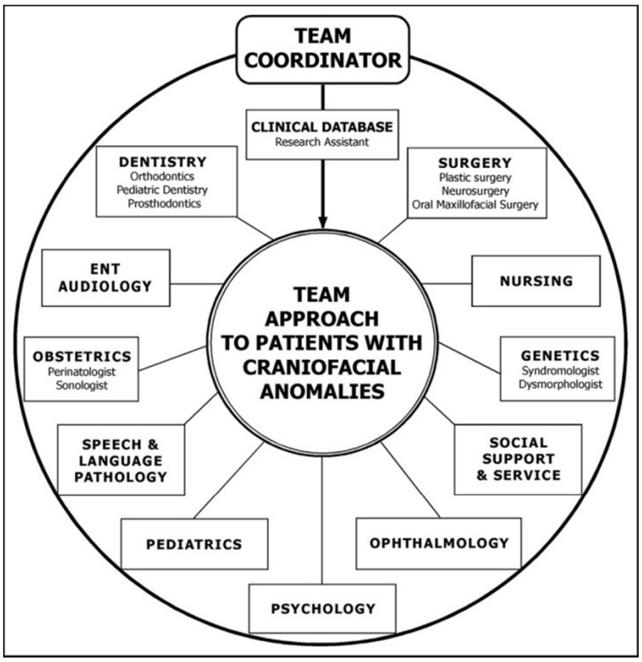

Fig. 1. *Members in the team approach to patients with craniofacial anomalies. (From Vig KWL, Mercado AM. Contemporary management of craniofacial anomalies: will past experiences influence and predict the future? In: McNamara JA Jr, editor. The 40th Moyers Symposium: Looking forward.looking back. Monograph 50.Craniofacial Growth Series. Ann Arbor: Center for Human Growth and Development; University of Michigan; 2014.)*

Most centers have adopted the principle of using well-defined time frames for treatment interventions in the context of a team approach. These conveniently fall into 4 stages with specific goals defined by periods of active orthodontic intervention followed by observation and rest periods.

2.1. Prenatal Period: Importance of Early Diagnosis

The technical improvements and wider use of ultrasonography, enabled pre-natal detection of development anomalies like orofacial clefts. This ability to make the diagnosis in utero allows the parents to be psychologically prepared for the birth of their infant with a facial difference [20-22]. In absence of prenatal diagnosis of a craniofacial anomaly, parents often experience an overwhelming sense of disappointment and guilt when the obstetrician informs them of their baby's birth defect. Once a craniofacial anomaly is detected prenatally, counseling is provided to parents before delivery by the members of the cleft palate- craniofacial team. The team's pediatric dentist or orthodontist may discuss with parents the dentoskeletal manifestations associated with clefts and offer an overview of the dental care required at the appropriate developmental stage. The plastic surgeon can discuss with the parents a customized plan for the management of the baby's cleft based on the severity of the deformity [23].

2.2. Neonatal Period: 2 Weeks to 6 Months

The goal of neonatal maxillary orthodontics was to eliminate the need for orthodontic treatment after the dentition erupted and did not include primary bone grafting. It was thought that on active and passive ideal alignment of the cleft segments in both unilateral and bilateral clefts of the lip and palate so that the teeth would erupt normally in their respective aligned segments. By treating at such an early age, the results would have to wait until the deciduous and permanent teeth erupted to convince the profession that early alignment of the segments with acrylic appliances did not eliminate orthodontic treatment. Modifications of appliances and primary bone grafting continued, but by the 1990s nasoalveolar molding (NAM) was gaining traction with the profession and was being reported in the Cleft Palate Journal[24].The intervention was typically performed by the orthodontist serving on the cleft palate and craniofacial team. With the use of an intraoral molding appliance and extraoral taping, the alveolar ridges are approximated within 1 to 2 mm of each other. The addition of nasal stents achieves lengthening of the columella in bilateral cleft patients. Ultimately, NAM prepares the infant for a 1-stage primary lip-nose repair between 3 and 5 months of age combined with gingivoperiosteoplasty to close the alveolar defect[25].The hard and soft tissue complications resulting from NAM are described by Levy-Bercowskiet al.[26] including recommendations on proper preventive and palliative measures. This technique is not without controversy, primarily in regard to the evidence supporting the benefits [27-29]. In 2014, the AJO-DO captured this controversy in the Point/Counterpoint articles by Grayson and Garfinkel[30](Point) and Hathaway and Long[31](Counterpoint).

2.3. Deciduous Dentition: 2 to 7 Years

Treatment in the deciduous dentition was popular in the 1930s and 1940s. However, most interventions were duplicated in the mixed dentition when the permanent teeth erupted. It therefore became prudent to delay most orthodontic interventions such as expansion and alignment of the incisors until the mixed dentition. With the development of the phonetic component of speech and language, articulation in the toddler is challenged by structural impairment. Lack of velopharyngeal competency and palatal mobility of the repaired cleft palate may result in adaptations by the child to reduce the hypernasality of speech and the development of glottal stops. To reduce the nasal air escape, a surgical pharyngeal flap may be suggested in which the soft palate is connected permanently to the superior anterior pharyngeal wall. Lip or nose revision surgeries are occasionally recommended for children before they start grade school.

2.4. Mixed Dentition: 7 to 12 Years

One major advantage for an orthodontist is having a successful alveolar bone graft in the cleft site into which the permanent canine erupts and brings additional alveolar bone. This requires close collaboration by the surgeon and orthodontist. Presurgical maxillary expansion is typically indicated; after the alveolar bone graft, the teeth adjacent to the cleft may be repositioned and moved into the sites without compromising their periodontal health. The controversies surrounding primary alveolar bone grafting resulted in some skepticism when secondary alveolar bone grafting was introduced in the oral surgery literature by Boyne and Sands[32] and adopted by cleft palate teams. It took 15 years before a landmark publication from the team in Oslo, Norway, provided strong evidence for the benefits of autologous secondary bone grafting using cancellous bone from the iliac crest; this remains the gold standard in the 21st century[33]. As the permanent teeth erupt, an association between cleft type and dental abnormalities of size, shape, and number becomes apparent, with the maxillary lateral incisor being the most vulnerable. The prevalence of "hypodontia" has been reported to increase with the severity of the cleft in both the deciduous and permanent dentitions [34].The circummaxillary sutures respond during the mixed dentition by modification and redirection of the nasomaxillary complex with protraction headgear. This became popular with orthodontists in the 1970s to correct the midface deficiency after its introduction by Delaire et al.[35]who applied the protraction force to prevent relapse after surgical maxillary advancement. Children with unilateral CLP typically have a midface deficiency, and their response to the protraction facemask has been studied for skeletal and dental outcomes after treatment [36].More recently, the introduction of bone-borne anchorage with miniplates and miniscrews provides an orthopedic force that can be applied to the maxilla[37,38].

2.5. Permanent Dentition: 12 Years to Adulthood

As growth stabilizes and the skeletal discrepancy is no longer a moving target, surgical corrections of the skeletal and nasolabial soft tissue revisions are planned. Adolescence is a difficult time for all young adults but especially if they have orofacial clefts. This special group of patients has already experienced multiple surgical procedures and nose and lip revisions. Speech may have deteriorated with velopharyngeal incompetency and the quality of life and social interactions impacted. Outcome measures of oral health–related quality of life of people with orofacial clefts have demonstrated significant psychological and social burdens. The adjustment of children to their facial deformity and scars is com- pounded by compromised speech and hearing disabilities. Functional and social-emotional well-being are reported to decrease their oral health–related quality of life, and the decrease is significantly greater in the 15 to 18-year-old subjects than in younger children with orofacial clefts[39]. After definitive jaw surgeries and growth stabilizes, dental implants are an option for restoration of missing maxillary incisors at the cleft site with high success rates if sufficient bone is provided by autogenous grafts and with implant lengths of at least 13 mm in the grafted alveolar sites [40]. More prospective clinical studies of dental implants in cleft sites are needed to improve the quality of evidence on their success rates [41]. Mesializing the maxillary canine into the lateral incisor space (canine substitution) is a common alternative to implants, yielding similar esthetic results [42].

3. Technical Advances in the 21st Century

3.1. Cone-Beam Computed Tomography

Cone-beam computed tomography (CBCT) technology is now available in orthodontic educational and private practice settings. Since 2005, the American Journal of Orthodontics & Dentofacial Orthopedics has published numerous articles on the applications of CBCT technology in orthodontic diagnosis and treatment planning. This 3-dimensional imaging of anatomic structures is especially valuable in evaluating cleft palate and other craniofacial skeletal anomalies. Hamada et al. [43] reported on the use of CBCT for the clinical assessment of alveolar bone grafting, demonstrating vertical and buccopalatal width measurements of the bone bridge. Wortcheet al.[44] used CBCT to evaluate axial and coronal sections through the cleft defect before alveolar bone grafting. Using volume-rendering software to analyze CBCT images, Oberoiet al.[45] objectively measured the amount of bone at the cleft site before and after alveolar bone grafting. As with any new technological advancement, the orthodontist is faced with the dilemma of the appropriateness of using CBCT in all patients or only in patients with clefts or craniofacial anomalies. In a special article by Abdelkarim [46] he advised that the prescription of radiographic imaging should be customized for each orthodontic patient, and thus not all patients (especially children) will require CBCT for diagnosis and treatment planning purposes. Specific to patients with clefts and craniofacial anomalies, Kuijpers-Jagtman et al.[47] overviewed the evidence for CBCT imaging in orthodontics and reported on 2 systematic reviews that support the use of CBCT in patients with orofacial clefts[48,49].There is a need to justify exposing all patients with orofacial clefts to CBCT, on any occasion, by performing a judicious clinical risk-benefit assessment.

3.2. Distraction Osteogenesis

Distraction osteogenesis (DO) stimulates formation of callous bone in a gap created through the gradual separation of osteotomized bone segments, resulting in effective lengthening of bones. The application of DO in infants to advance the severely underdeveloped mandible has improved the airway and feeding, eliminating the long-term need for a tracheostomy or feeding tube [50]. Another application of this technique, specifically for reconstruction of the mandible in hemifacialmicrosomia, was reported by McCarthy[51]. Orthodontists have played an integral role in collaborations to develop craniofacial applications of DO in the mandible [50-52] and in surgical maxillary advancement for severe cleft maxillary hypoplasia[53].

The DO technique gradually protracts the surgically mobilized maxilla by stretching the scarred palatal tissues in small increments and allowing adaptation of the soft tissues including the velophryngeal mechanism. The technique of rigid external distraction initially involves cementation of an intraoral tooth-borne splint in the maxilla with extraoral extensions (hooks) for traction [53,54]. The use of internal distractors in the cleft maxilla has the added benefit of long consolidation periods [55].More recent applications of the principles of DO are directed specifically at closing or reducing the size of large alveolar clefts. Alveolar bone transport has been used to move osteotomizeddentoalveolar posterior segments anteriorly, in both bilateral and unilateral cleft patients[56,57]. Vertically directed distraction of an edentulous bone segment on a previously grafted site can improve the esthetic outcome resulting from dental implant placement [58].

3.3. Temporary Anchorage Devices or Miniscrews (TADs)

Temporary anchorage devices or miniscrews allow the orthodontist to move selected teeth without causing unwanted reactive movements of adjacent teeth when inserted into strategic areas on the maxilla or mandible. Their small size (most commonly less than 2.5 mm in diameter, and 4-10 mm in length), mechanical retention in cortical bone, and lack of osseointegration allow for simple implantation, immediate loading, stability, and easy explantation. Miniscrews commonly used in orthodontic practices have multiple applications in patients with clefts and other craniofacial anomalies. They can be used to stabilise, intrude, or align an edentulous and mobile premaxilla before alveolar bone grafting in patients with bilateral cleft lip and palate[59]TADs have also been used to align teeth[60], guide skeletal movements during DO[61] , correcting maxillary occlusal cant [61], provide skeletal anchorage during orthopedic maxillary protection[62]as well as stabilise intramural distracters[63]

3.4. Finite Element Method (FEM)

Finite element analysis is a mathematical method in which the shape of complex geometric objects and their physical properties are computer constructed. Interactions of various components of the model are then calculated for stress, strain, and deformation. FEM thus enables us to visualise the effects of externally applied forces on biologic systems. This has proved useful in studying the effect of orthopedic appliances in cleft patients [64].

4. Evaluation of Treatment Outcomes

As with any child born with a congenital anomaly, it is important to evaluate the outcomes of treatment interventions in patients with CLP so that they can be related to the burden of care perceived by the patient and the caregivers. This yields information about the risk-benefit ratio of treatment, empowers the family during the informed consent process, and contributes to patient-centered care to maximize the patient's QOL. However, there is often a lack of agreement among clinicians on the best way to assess and measure the outcomes of their interventions.

Contemporary measures that are reliable and valid have been developed to assess outcomes in the Eurocleft consortium. Six European cleft palate teams shared outcome data from their primary infant management protocols. This novel approach demonstrated the value of conducting intercenter studies to compare treatment outcomes using retrospective records [66-70].

Although the results cannot identify which individual procedures in a primary infant management protocol are responsible for a favorable or an unfavorable outcome, the results from the Eurocleft study eventually led to changes in previously accepted treatment interventions. Because of the retrospective nature of the study, some uncertainty prevailed, and investigators emphasized the need for prospective randomized clinical trials.

The Dutchcleft initiative in 1993 was conducted as an intercenter randomized clinical trial to study infant orthopedics in patients with unilateral CLP [71-72]. The study reported that subjects who had infant orthopedics did not show any long-term benefits when followed to the age of 12 years. As a result of the study, all centers in Netherlands have now discontinued infant orthopedics. Unfortunately, randomized clinical trials are expensive to conduct, and interventions in the neonatal period require long-term follow-ups because growth and development of the nasomaxillary complex continue until late adolescence.

In the United States, the Craniofacial Outcomes Registry was supported by the National Institutes of Health and the National Institute of Dental and Craniofacial Research to develop a registry of teams, measure various outcomes, and aggregate the collected data for intercenter comparisons. Although several teams entered into the registry, controversy resulted from lack of agreement on which outcome variables should be measured. Even though there are many well-organized centers with high volumes of patients, cleft-craniofacial teams in North America were unable to develop an ongoing intercenter, collaborative clinical initiative to include multiple teams throughout the United States.

4.1. Americleft Intercenter Study

The success of the more limited Eurocleft study of the 1980s provided the impetus to initiate intercenter outcome studies in North America. In 2006, recognizing the lack of collaborative research in North America, the ACPA established a "task force on intercenter collaborations" as part of its Research Committee to initiate the Americleft study based on the Eurocleft model. The 6-center Americleft study was successful at attracting centers that differ in their "primary infant management protocols." All these centers followed the same methodologic considerations that were established for the Americleft study [73]. Five North American centers (A-E) agreed to participate in the Americleft study and met the key methodologic considerations. Centers A through E used standardized protocols with wide variations among centers. Protocols for each center are summarized in Table 1.

Table 1. *Sample characteristics and treatment protocols for the Americleft study centers.*

Treatment	Center A	Center B	Center C	Center D	Center E	Center F
Sample Size & Sex	18 (10 M/8 F)	40 (28 M/12 F)	41 (25 M/16 F)	38 (29 M/9 F)	35 (21 M/14 F)	32 (24 M/8 F)
Presurgicalorthopaedics	No	Yes*	No	Yes[y]	Yes[z]	Yes[§] NAM
Primary lip repair	6-12 w Millard or 5-6 moDelaire	2-3 mo Millard	3 mo Tennison	3 mo Millard	3-4 mo Millard	3-5 mo modified Millard
Primary nasal repair	No	No	No	No	No	Yes 3-5 mo with lip repair
Primary bone grafting	No	Yes, 6-9 mo	No	No	No	No (GPP in 5/32)
Hard palate repair	9-12 mo Bardach or Delaire	11-15 mo Hard palate Wardill-Kilner	12 mo Vomer flap	12 mo Wardill and Vomer flap	12-14 mo Vomer flap/V-L	12 mo Bardach or repair flap 18 mo V-L
Soft palate repair	9-12 moBardach or 5-6 moDelaire	11-15 mo IVP or some Furlow (1 surgeon)	18 mo Median suture with IVP	12 moWardill and Vomer flap	12-14 moVeau pushback	12 mo IVP with Bardach or 3-5 mo IVP then V-L at 18 mo
Secondary bone grafting	6-7 y Delaire	8-9 y if needed	9 y	7-10 y	9-11 y	9-10 y
Nose/lip revisions	4-5 y	4-5 y	14-20 y	4-5 y	4-7 y	None done on this sample
Surgeons	2	4	1	4	4	2

M, Male; F, female; GPP, gingivoperiosteoplasty; V-L, Von-Langenbeck; IVP, intravelar veloplasty.*Center B. The molding plate was started at 2-3 months and continued through primary bone grafting to the palate repair at 11-15 months. The molding was discontinued at the time of palate repair; [y]Center D. Infant presurgical orthopedic treatment was done using a modified McNeil technique with extraoral traction. The orthopedic appliance was placed before lip repair at 3 months and discontinued once lip repair was done; [z]Center E. Infant presurgical orthopedic treatment was done using a modified McNeil technique with extraoral traction. The orthopedic appliance was placed before lip repair at 3-4 months and continued until the time of palate repair at 12-14 months; [§]Center G. NAM with lip taping was started within the first 2 weeks. Patients wore appliance for 3-4 months until lip repair.FromVig KWL, Mercado AM. Contemporary management of craniofacial anomalies: will past experiences influence and predict the future? In: McNamara JA Jr, editor. The 40th Moyers Symposium: Looking forward. Looking back.Monograph 50. Craniofacial Growth Series. Ann Arbor: Center for Human Growth and Development; University of Michigan; 2014.

The treatment outcomes assessed were dental arch relationships on dental casts, skeletal andsoft tissue craniofacial morphologies, and nasolabial esthetics.

The following publications were derived from this study & reported the results for each outcome.

Dental arch relationships [74]. The Goslon yardstick was used to objectively classify the severity of the maxillomandibular dental relationships[75]. The highest Goslon mean score was for center B, indicating the poorest outcome in the study and suggesting that patients in this center were at higher risk of needing maxillary orthognathic advancement surgery. The lowest Goslon mean score was for center C, indicating the best outcome among centers.

Craniofacial morphology analysis [76]. Intercenter comparisons of skeletal and soft tissue profiles included centers B, C, D, and E. Significant intercenter differences were found in SNA and ANB angles. Center B had the smallest maxillary prominence, whereas center C had the highest maxillary prominence. However, measures of mandibular prominence, vertical dimensions, and dental inclinations showed no differences among centers. There was a significant but moderate negative correlation between the Goslon rating on the dental models and the corresponding subject's ANB angle.

Nasolabial esthetics [77]. Intercenter comparisons of nasolabial esthetic outcomes were done on the facial images of subjects from centers B, C, D, and E. Four features were rated: nasal form, symmetry, profile, and shape of the vermilion border[78].The mean scores for each center for the features assessed were in the good-to-fair range, with no significant differences among centers.

Analyses of the results from the original Americleft study confirmed that a retrospective review to study intercenter outcomes using diagnostic clinical records can provide information about favorable and unfavorable outcomes in patients with complete unilateral CLP. Center B, where the treatment protocol included infant orthopedics, primary alveolar bone grafting, and secondary surgical revisions before the mixed dentition stage, had the worst mean Goslon score. This was similar to the Eurocleft study, which also found that centers that used primary alveolar bone grafting and infant orthopedics had less favorable outcomes than did centers that used simpler protocols. Therefore, the information derived from the intercenter studies suggested that centers should avoid complicated primary infant management protocols, including infant orthopedics and primary alveolar bone grafting[79].

4.2. Extensions of the Americleft Study

The initial Americleft study was published as a 5- article series in 2011. Subsequently, the investigators have extended their studies to include a center routinely providing the infant presurgical technique of NAM as part of its primary infant management protocol, not used in any of the original centers. The study was designed to compare outcomes of dental arch relationships, skeletal morphology, and nasolabial esthetics among 4 centers using different primary infant protocols including NAM. The centers included were B, C, D, and G (Table I).

The results suggested that the inclusion of NAM in the primary infant management protocol was not associated with a significant improvement in dental arch relationships and craniofacial morphology when compared with protocols with other types of presurgical infant orthopedics [80,81].In regard to nasolabial esthetic outcomes, center G's mean scores were generally more favorable than those of centers B, C, and D[82].

This Americleft extension study suggests that the nasolabial esthetic outcomes are generally better when the primary infant management protocols include NAM or secondary revision surgeries. A burden of care analysis would help to justify performing NAM during infancy, compared with waiting until adolescence for secondary revision surgery.

Other extensions of the Americleft study include development of a rating scale for assessing bone graft outcomes[83],proposal of an expanded yardstick for nasolabial appearance outcomes[84],analysis of the burden of care from secondary surgeries[85],and reliability studies for the evaluation of intercenter speech outcomes[86].

5. Craniofacial Orthodontic Fellowship Programs

Because the orthodontist is now expected to treat craniofacial anomalies at a level of proficiency above the accreditation requirements in an orthodontic residency, the development of clinical fellowships in craniofacial and special-care orthodontics has gained recognition. These are typically 1-year programs after an advanced specialty program in orthodontics, with an immersion in the treatment of patients with craniofacial anomalies, medically compromised patients, or those with developmental disabilities in an established craniofacial center. These fellowship programs may be accredited through hospitals or through the Commission on Dental Accreditation with approval by the American Association of Orthodontists. The number and demand of orthodontists to enroll in an accredited craniofacial fellowship program have been increasing dramatically in the past 5 years. The intention of these craniofacial fellowships is to provide orthodontists with additional skills to equip them to manage and treat more complex orthodontic patients in the context of the whole team[87,88].

6. Conclusion

The treatment of orofacial clefts has come a long way over the past century. The modalities and approaches used today are in many cases diametrically opposite to those used about 100 years ago. Technological and scientific breakthroughs have improved our understanding and enhanced treatment success. Newer approaches have not only taken into account operational factors but also considered psychological factors. The patient & caregiver have never before occupied the position of paramount importance in the treatment cycle that they rightly do today. Treatment of orofacial clefts over the next century looks promising. The emergence of TADs and mini plates has opened up new avenues of treatment which could not be fathomed about a decade ego. Fledgling sciences like genetic engineering, stem-cell therapy and nanotechnology could be potential game changers in the prevention, detection as well as correction of orofacial clefts.

References

[1] Wig KW, Mercado AM. Overview of orthodontic care for children with cleft lip and palate, 1915-2015.Am J OrthodDentofacialOrthop 2015;148:543-56.

[2] Eby JD. Maximum improvements in congenital orofacial clefts. Am J Orthod 1956; 42:867-72.

[3] Kiskadden WS, Tholen EF. Primary and secondary repair of cleft lip. Int J Orthod Oral SurgRadiogr 1932; 18:863-73.

[4] Davis AL. Cleft lip and palatal surgical correction. Am J Orthod Oral Surg 1932; 18:282-90.

[5] Millard DR Jr. Uranoplasty by maxillary compression, Cleft craft: the evolution of its surgery. Volume III: alveolar and palatal deformities. Boston: Little, Brown and Company; 1980. p. 223-30.

[6] Drachter R. The cleft palate and their surgical treatment. Dtsch Z Chir 1914; 131:1-89.

[7] Ivy RH. Review of recent literature on cleft lip and palate surgery. Am J Orthod Oral Surg 1937; 23:844-9.

[8] Webster RC .Title matter. Cleft Palate J 1964; 1:1-16.

[9] Salzmann JA. Northwestern University Cleft Lip and Palate Institute. Am J Orthod Oral Surg 1953; 39:487-8.

[10] Graber TM. Thecongenital cleft palate deformity. J Am DentAssoc 1954; 48:375-95.

[11] Pruzansky S. Presurgicalorthopaedics and bone grafting for infants with cleft lip and palate: a dissent. Cleft Palate J 1964; 1:164-82.

[12] Jolleys A, Robertson NRE. A study of the effects of early bone grafting in complete clefts of the lip and palate—five year study. Br J PlastSurg 1972;25:229-37.

[13] Rosenstein SW. A new concept in the early orthopaedic treatment of cleft lip and palate. Am J Orthod Oral Surg 1969; 56:529-30.

[14] Rosenstein SW, Monroe CW, Kernahan DA, Jacobson BN, Griffith BH, Bauer BS. The case for early bone grafting. J Oral Surg 1982; 70:297-330.

[15] Burston WR. The early treatment of cleft palate conditions. Dent Prac 1953;9:41-52.

[16] McNeil CK. Oral and facial deformity. London, United Kingdom: Sir Isaac Pitman & Sons; 1954.

[17] Ross RB, Johnston MC. The effects of early orthodontic treatment on facial growth in cleft lip and palate. Cleft Palate J 1967;4: 157-64

[18] Horowitz SL, Berkowitz S, Broadway ES, Gorlin R, Hixon EH, Pruzansky S, Ross RB. Cleft lip and cleft palate: research relevant to clinical management in dentistry. An NIDR state of the art report. Subcommittee on Dentistry. Am J Orthod 1973;63:398-406.

[19] Vig K, Mercado A. The orthodontist's role in a cleft palate-craniofacial team. In: Graber LW, Vanarsdall RL, Vig KW, editors. Orthodontics: current principles and techniques. 5th ed. Philadelphia: Elsevier Mosby; 2012. p. 965-89.

[20] Cooper HK, Harding RL, Krogman WM, Mazaheri DS, Millard RT. Cleft palate and cleft lip: a team approach to clinical management and rehabilitation of the patient. Philadelphia: W. B. Saunders; 1979.

[21] Johnson N, Sandy JR. Prenatal diagnosis of cleft lip and palate. Cleft Palate Craniofac J 2003;40:186-9.

[22] Mulliken JB, Benacerraf BR. Prenatal diagnosis of cleft lip: what the sonologist needs to tell the surgeon. J Ultrasound Med 2001;20:1159-64.

[23] Mercado AM, Vig KW. Orthodontic principles in cleft lip and palate care. In: Losee JE, Kirschner RE, editors. Comprehensive cleft care. New York: McGraw-Hill, Medical Publishing Division; 2009. p. 721-47.

[24] Grayson BH, Santiago PE, Brecht LE, Cutting CB. Presurgicalnasoalveolar molding in infants with cleft lip and palate. Cleft Palate Craniofac J 1999;36:486-98.

[25] Grayson BH, Maull D. Nasoalveolar molding for infants born with clefts of the lip, alveolus, and palate. ClinPlastSurg 2004; 31: 149-58.

[26] Levy-Bercowski D, Abreu A, DeLeon E, Looney S, Stockstill J, Weiler M, et al. Complications and solutions in presurgicalnasoalveolar molding therapy. Cleft Palate Craniofac J 2009;46:521-8.

[27] Van der Heijden P, Dijkstra PU, Stellingsma C, van der Laan BF, Korsten-Meijer AG, Goorhuis-Brouwer SM. Limited evidence for the effect of presurgical nasoalveolar molding in unilateral cleft on nasal symmetry: a call for unified research. Plast Reconstr Surg 2013;131:62e-71e.

[28] Smith DM, Macisaac ZM, Losee JE. Discussion: limited evidence for the effect of presurgicalnasoalveolar molding in unilateral cleft on nasal symmetry: a call for unified research. PlastReconstrSurg 2013;131:72e-4e.

[29] Grayson BH. Discussion: limited evidence for the effect of presurgicalnasoalveolar molding in unilateral cleft on nasal symmetry: a call for unified research. PlastReconstrSurg 2013;131:75e-6e.

[30] Grayson BH, Garfinkel JS. Early cleft management: the case for nasoalveolar molding (Point/Counterpoint). Am J OrthodDentofacialOrthop2014;145:134-40.

[31] Hathaway RR, Long RE Jr. Early cleft management: in search of evidence (Point/Counterpoint). Am J OrthodDentofacialOrthop 2014;145:135-42.

[32] Boyne PJ, Sands NR. Secondary bone grafting of residual alveolar and palatal clefts. J Oral Surg 1972;30:87-92.

[33] Bergland O, Semb G, Abyholm FE. Elimination of the residual alveolar cleft by secondary bone grafting and subsequent orthodontic treatment. Cleft Palate J 1986;23:175-205.

[34] Ranta R. A review of tooth formation in children with cleft lip/palate. Am J OrthodDentofacialOrthop 1986;90:11-8.

[35] Delaire J, Verdon P, Kenesi MC. Extraoral traction forces with forehead-chin-supporting for the treatment of maxillary deformities as a result of cleft lip and cleft palate. FortschrKieferorthop1973;34:225-37.

[36] So LL. Effects of reverse headgear treatment on sagittal correction in girls born with unilateral cleft lip and palate—skeletal and dental changes. Am J OrthodDentofacialOrthop 1996;109:140-7.

[37] De Clerck HJ, Cornelis MA, Cevidanes LH, Heymann GC, Tulloch CJ. Orthopedic traction of the maxilla with miniplates: a new perspective for treatment of midface deficiency. J Oral Max- illofacSurg 2009; 67:2123-9.

[38] Baek SH, Kim KW, Choi JY. New treatment modality for maxillary hypoplasia in cleft patients: protraction face mask with miniplate anchorage. Angle Orthod 2010;80:783-91.

[39] Ward JA, Vig KW, Firestone AR, Mercado A, da Fonseca M, Johnston W. Oral health-related quality of life in children with oro-facial clefts. Cleft Palate Craniofac J 2013;50:174-81.

[40] Pena W, Vargervik K, Sharma A, Oberoi S. The role of endosseous implants in the management of alveolar clefts. Pediatr Dent 2009; 37:329-33.

[41] Wermker K, Jung S, Joos U, Kleinheinz J. Dental implants in cleft lip, alveolus, and palate patients: a systematic review. Int J Oral Maxillofac Implants 2014;29:384-90.

[42] Oosterkamp BC, Dijkstra PU, Remmelink HJ, van Oort RP, Sandham A. Orthodontic space closure versus prosthetic replacement of missing upper lateral incisors in patients with bilateral cleft lip and palate. Cleft Palate Craniofac J 2010;47:591-6.

[43] Hamada Y, Kondoh T, Noguchi K, Iino M, Isono H, Ishii H, et al. Application of limited cone beam computed tomography to clinical assessment of alveolar bone grafting: a preliminary report. Cleft Palate Craniofac J 2005;42:128-37.

[44] Wortche R, Hassfeld S, Lux CJ, Mussig E, Hensley FW, Krempien R, et al. Clinical application of cone beam digital volume tomography in children with cleft lip and palate. DentomaxillofacRadiol 2006; 35:88-94.

[45] Oberoi S, Chigurupati R, Gill P, Hoffman WY, Vargervik K. Volu- metric assessment of secondary alveolar bone grafting using cone beam computed tomography. Cleft Palate Craniofac J 2009;46:503-11.

[46] Abdelkarim AA. Appropriate use of ionizing radiation in orthodontic practice and research. Am J OrthodDentofacialOrthop 2015; 147:166-8.

[47] Kuijpers-JagtmanAM, Kuijpers MAR, Schols JGJH, Maal TJJ, Breuning KH, van Vlijmen OJC. The use of cone-beam computed tomography for orthodontic purposes. SeminOrthod 2013;19:196-203.

[48] Van Vlijmen OJC, Kuijpers MAR, Berg e SJ, Schols JG, Maal TJ, Breuning H, et al. Evidence supporting the use of cone-beam computed tomography in orthodontics. J Am Dent Assoc 2012; 143:241-52.

[49] SEDENTEXCT project. Radiation protection no. 172: cone beam CT for dental and maxillofacial radiology. Evidence based guidelines 2012. Available at: http://www.sedentexct.edu/content/guideline s-cbct-dental-and-maxillofacial-radiology.

[50] McCarthy JG, Schreiber JS, Karp NS, Thorne CH, Grayson BH. Lengthening the human mandible by gradual distraction. Plast Re- constrSurg 1992;89:1-8.

[51] McCarthy JG. The role of distraction osteogenesis in the reconstruction of the mandible in unilateral craniofacial microsomia. ClinPlastSurg1994;21:625-31.

[52] McCarthy JG, Staffenberg DA, Wood RJ, Cutting CB, Grayson BH, Thorne CH. Introduction of an intraoral bone-lengthening device. PlastReconstrSurg 1995;96:978-81.

[53] Figueroa AA, Polley JW. Management of severe cleft maxillary deficiency with distraction osteogenesis: procedure and results. Am J OrthodDentofacialOrthop 1999;115:1-12.

[54] Minami K, Mori Y, Tae-Geon K, Shimizu H, Ohtani M, Yura Y. Maxillary distraction osteogenesis in cleft lip and palate patients with skeletal anchorage. Cleft Palate Craniofac J 2007;44:137-41.

[55] Kumar A, Gabbay JS, Nikjoo R, Heller JB, O’Hara CM, Sisodia M, et al. Improved outcomes in cleft patients with severe maxillary deficiency after Le Fort I internal distraction. PlastReconstrSurg 2006;117:1499-509.

[56] Dolanmaz D, Karaman AI, Durmus E, Malkoc S. Management of alveolar clefts using dento-osseous transport distraction osteogenesis. Angle Orthod 2003;73:723-9.

[57] Zemann W, Pichelmayer M. Maxillary segmental distraction in children with unilateral clefts of lip, palate, and alveolus. Oral Surg Oral Med Oral Pathol Oral RadiolEndod 2011; 111:688-92.

[58] Rachmiel A, Emodi O, Aizenbud D. Three-dimensional reconstruction of large secondary alveolar cleft by two-stage distraction. Cleft Palate Craniofac J 2014;51:36-42.

[59] Bohman P, Yamashita DD, Baek SH, Yen SL. Stabilization of an edentulous premaxilla for an alveolar bone graft: case report. Cleft Palate Craniofac J 2004;41:214-7.

[60] Proff P, Bayerlein T, Gedrange T. Special features of planning and application of orthodontic miniscrews in cleft patients. J Cranio- maxillofacSurg 2006;34(Suppl 2):73-6.

[61] Vachiramon A, Urata M, Kyung HM, Yamashita DD, Yen SL. Clinical applications of orthodontic microimplant anchorage in craniofacial patients. Cleft Palate Craniofac J 2009;46:136-46.

[62] Yen SL. Protocols for late maxillary protraction in cleft lip and palate patients at Children’s Hospital, Los Angeles. SeminOrthod 2011;17:138-48.

[63] Rachmiel A, Emodi O, Gutmacher Z, Blumenfeld I, Aizenbud D. Oral and dental restoration of wide alveolar cleft using distraction osteogenesis and temporary anchorage devices. J CraniomaxillofacSurg 2013;41:728-34.

[64] Gautam P, Zhao L, Patel P. Biomechanical response of the maxillofacial skeleton to transpalatal orthopedic force in a unilateral palatal cleft. Angle Orthod. 2011;(81)3:507–515.

[65] Shet KV, Shetty KN, Rai R, Mahale AD. Stress distribution and displacement of craniofacial structures following force application in treatment of an operated bilateral facial cleft. Turkish J Orthod. 2015;27:148–157

[66] Shaw WC, Asher-McDade C, Brattstro€m V, Dahl E, McWilliam J, Mølsted K, et al. A six-center international study of treatment outcome in patients with clefts of the lip and palate: part 1. Principles and study design. Cleft Palate Craniofac J 1992;29:393-7.

[67] MølstedK,Asher-McDadeC,BrattstromV,DahlE,Mars M, McWilliam J, et al. A six-center international study of treatment outcome in patients with clefts of the lip and palate: part 2. Craniofacial form and soft tissue profile. Cleft Palate Craniofac J 1992;29:398-404.

[68] Mars M, Asher-McDade C, Brattstrom V, Dahl E, McWilliam J, Mølsted K, et al. A six-center international study of treatment outcome in patients with clefts of the lip and palate: part 3. Dental arch relationships. Cleft Palate Craniofac J 1992; 29:405-8.

[69] Asher-McDade C, Brattstrom V, Dahl E, McWilliam J, Mølsted K, Plint DA, et al. A six-center international study of treatment outcome in patients with clefts of the lip and palate: part 4. Assessment of nasolabial appearance. Cleft Palate Craniofac J 1992; 29: 409-12.

[70] Shaw WC, Dahl E, Asher-McDade C, Brattstrom V, Mars M, McWilliam J, et al. A six-center international study of treatment outcome in patients with clefts of the lip and palate: part 5. General discussion and conclusions. Cleft Palate Craniofac J 1992;29:413-8.

[71] Prahl C, Kuijpers-Jagtman AM, Van’t Hof MA, Prahl-Andersen B. A randomised prospective clinical trial into the effect of infant orthopedics on maxillary arch dimensions in unilateral cleft lip and palate(Dutchcleft). Eur J Oral Sci 2001;109:297-305.

[72] Prahl C, Kuijpers-Jagtman AM, Van't Hof MA, Prahl-Andersen B. Infant orthopedics in UCLP: effect on feeding, weight, and length. A randomized clinical trial (Dutchcleft). Cleft Palate Craniofac J 2005;42:171-7.

[73] Long RE Jr, Hathaway RR, Daskalogiannakis J, Mercado AM, Russell KA, Cohen MA, et al. The Americleft study: an intercenter study of treatment outcomes for patients with unilateral cleft lip and palate. Part 1—principles and study design. Cleft Palate Craniofac J 2011;48:239-43.

[74] Hathaway RR, Daskalogiannakis J, Mercado AM, Russell KA, Long RE Jr, Cohen MA, et al. The Americleft study: an intercenter study of treatment outcomes for patients with unilateral cleft lip and palate. Part 2—dental arch relationships. Cleft Palate Craniofac J 2011;48:244-51.

[75] Mars M, Plint DA, Houston WJ, Bergland O, Semb G. The Golson yardstick: a new system of assessing dental arch relationships in children with unilateral clefts of the lip and palate. Cleft Palate J 1987;24:314-22.

[76] Daskalogiannakis J, Mercado AM, Russell KA, Hathaway RR, Dugas GS, Long RE Jr, et al. The Americleft study: an intercenter study of treatment outcomes for patients with unilateral cleft lip and palate. Part 3—analysis of craniofacial form. Cleft Palate Craniofac J 2011;48:252-8.

[77] Mercado AM, Russell KA, Hathaway RR, Daskalogiannakis J, Sadek H, Long RE Jr, et al. The Americleft study: an intercenter study of treatment outcomes for patients with unilateral cleft lip and palate. Part 4—nasolabial esthetics. Cleft Palate Craniofac J 2011;48:259-64.

[78] Asher-McDade C, Roberts C, Shaw WC, Gallagher C. Development of a method for rating nasolabial appearance in patients with clefts of the lip and palate. Cleft Palate Craniofac J 1991;28:385-90.

[79] Russell KA, Long RE Jr, Hathaway RR, Daskalogiannakis J, Mercado AM, Cohen MA, et al. The Americleft study: an intercenter study of treatment outcomes for patients with unilateral cleft lip and palate. Part 5—general discussion and conclusions. Cleft Pal- ate Craniofac J 2011;48:265-70.

[80] Peanchitlertkajorn S, Russell K, Daskalogiannakis J, Lamichane M, Mercado A, Hathaway RR, et al. An expansion of the Americleft in- tercenter comparison of dental arch relationships to include a center using NAM 6 GPP as part of its primary protocol [abstract 13]. Fort Worth, Tex: ACPA 67th Annual Meeting; 2010, March 16-20.

[81] Peanchitlertkajorn S, Daskalogiannakis J, Lamichane M, Mercado A, Hathaway RR, Russell K, et al. A multicenter retrospective study of patients with CUCLP from 5 North-American centers [abstract 191]. San Juan, Puerto Rico: ACPA 68th Annual Meeting; 2011, April 5-9.

[82] Mercado AM, Peanchitlertkajorn S, Daskalogiannakis J, Hathaway R, Lamichane M, Russell K, et al. An expansion of the Americleftintercenter comparison of nasolabial appearance out- comes to include a center using NAM as part of its primary proto- col [abstract 15]. San Juan; Puerto Rico: ACPA 68th Annual Meeting; 2011, April 5-9.

[83] Russell K, Long RE Jr, Daskalogiannakis J, Mercado A, Hathaway R, Semb G, et al. A multicenter study using the SWAG scale to compare secondary alveolar bone graft outcomes for patients with cleft lip and palate. Cleft Palate Craniofac J 2015 [Epub ahead of print].

[84] Mercado AM, Russell KA, Daskalogiannakis J, Hathaway RR, Semb G, Ozawa T, et al. The Americleft project: a proposed expanded nasolabial appearance yardstick for 5- to 7-year-old patients with complete unilateral cleft lip and palate (CUCLP). Cleft Palate Craniofac J 2015 [Epub ahead of print].

[85] Sitzman TJ, Mara CA, Long RE Jr, Daskalogiannakis J, Russell KA, Mercado AM, et al. The Americleft project: burden of care from secondary surgery. PlastReconstrSurg Glob Open 2015;3:e442 [Epub ahead of print].

[86] Chapman KL, Baylis A, Trost-Cardamone J, Cordero KN, Dixon A, Dobbelsteyn C, et al. The Americleft speech project: a training and reliability study. Cleft Palate Craniofac J 2014 [Epub ahead of print].

[87] McCarthy JG. Development of craniofacial orthodontics as a sub- specialty at New York University Medical Center. SeminOrthod 2009; 15:221-4.

[88] Santiago PE, Grayson BH. Introduction. SeminOrthod 2009; 15: 219-20.