CHAPTER 2

LITERATURE REVIEW

2.1 Incidence of cleft

Cleft lip and/or palate are the most common craniofacial anomalies. The prevalence is high approximately 1-2 per 1,000 live births[1] and varies with race and the type of cleft. The overall incidence of cleft lip ranges from 1.45 to 1.57 per 1000 in Europe. Orientals show a higher, and black people a lower incidence.[2] The most recent data from American Cleft Palate Educational Foundation reports about 1 in 700 live white births have a cleft lip or palate. For Orientals, In Japan, the incidence of cleft is about 1 in 584 live births. In Singapore it is about 1 in 574 live births.[3] In Thailand, Chuangsuwanich and Aojanepong[4] reported 1 in 546-698 live births having a cleft lip or palate. Cleft type divided into 23% had cleft lip only, 60% had cleft lip and palate, and 17% had cleft palate only. Patients with cleft lip or cleft lip and palate were born less often in winter than in summer. A history of family members having clefts occurred in 6.84% of patients.[5] The proportion of cleft lip and palate cases was higher than that of cleft lip patients. In Thailand, men predominated all groups except for the cleft palate-only group. 26% had associated congenital anomalies. 21.6% had a history of cleft lip and palate in their first- and second-degree relatives. 52.74% had a history of taking drugs. Analgesics were among the drugs taken most often.[4] 59% of these patients were in the North East region of Thailand. Location of cleft affected side were 24% right, 24% bilateral and 52 % left side.[6]

2.2 Classification of cleft

The first cleft classification was described by Veau[7]. He describe 4 types of cleft which consist of cleft of soft palate, cleft of soft and hard palate, unilateral complete cleft and bilateral complete cleft. His classification was easily to identify but lacking in severity details.(Figure 2.1)

Classification of cleft anomalies was also published by Pfeifer.[7] Kernahan was introduced "striped Y" diagram in 1971.[8] His diagram the Y-arms represented to primary palate (left and right sides forward position to incisive foramen) and the Y-stem represented the primary palate (behind incisive foramen).(Figure 2.2)

Elashy[9] published a modified Kernahan classification by addition of nostril floor involvement and pre-maxilla rotation into the records. The recording of nasal arch deformity was introduced by Millard[10] since he added the inverted triangles to represented the nasal arches. The most favorite recent diagram was introduced by Friedman *et al*.[11] They combine the striped Y shaped of Elashy and Millard and represented the severity of the deformity by shading and stippling of block and a numerical system.

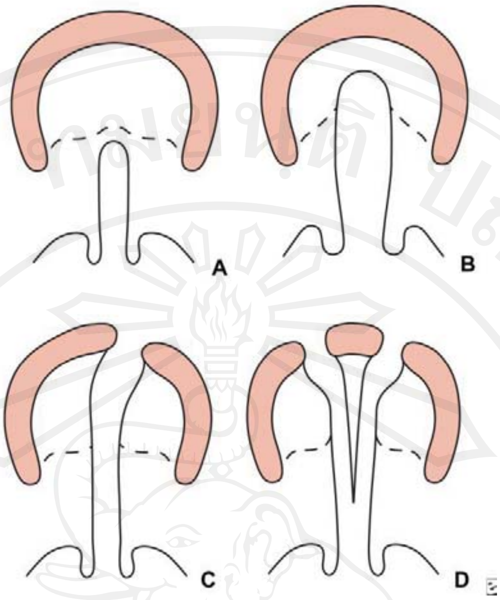
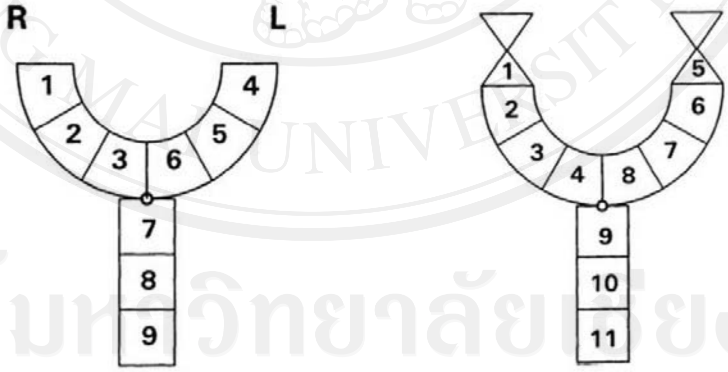


Figure 2.1 Veau's classification A) Cleft of soft palate B) Cleft of soft and hard palate C) Unilateral complete cleft D) Bilateral complete cleft



A B

Figure 2.2 Classification of clefts A) Kernahan's classification

B) Millard's classification

2.3 Characteristic of Cleft

Patients with cleft lips and palates are generally characterized by abnormalities of the dental arch form, malocclusions, facial deformity, and masticatory dysfunction. Patients with Unilateral cleft lip and/or palate show a deficiency of soft tissues, insufficient bone support, malformation and hypodontia of the teeth near and in the cleft, deficient sagittal maxillary growth and transverse collapse of the upper jaw, midline deviation, and a vertically short midface.[12] Some dental traits such as hypodontia, supernumerary teeth, peg-shaped teeth, crown and root malformations, dental asymmetry, and delay in tooth development may occur with a higher frequency in patients with UCLP on the cleft side.[13] The idea that the same etiological factors (poly- or monogenetic inheritance and multiple exogenous factors) that cause the formation of the cleft can affect development of the dentition is supported by several authors.[14] The incidence of hypodontia outside the cleft area in patients with UCLP is also markedly increased (27.8%), compared with noncleft controls (3.6%).[13] In particular, second premolars on both sides in the upper jaw and lateral incisors are most frequently missing.[15] Supernumerary teeth in patients with a cleft are often seen in the deciduous dentition[16], particularly in isolated clefts of the lip. The opposite was found with regard to hypodontia by Brattstorm and McWilliams[17], who found that the prevalence of hypodontia increased in proportion to cleft severity. Moreover, according to Berkowitz[18] a cleft of the lip and/or palate is "a structural defect that usually affects other functional areas" (e.g. speech, hearing, feeding) and causes repeated middle-ear infections.

2.4 Lip repair

Lip closure of the unilateral cleft lip with local flaps was first described by Malgaigne.[19] The following year, Mirault was modified Malgaigne's technique by using lateral lip flap to fill out the medial defect.[20] All future methods of cleft lip closure are based on Mirault's technique. Rose[21] was introduced cleft lip repaired by using straight-line closure technique in 1891. In 1881, Hagedorn[22] applied Z-plasty technique. Le Mesurier[23] and Tennison[24] modified the technique of lateral flap tissue in 1950's and 1960's. In 1976, Millard[25] published his definitive repair in which the lateral flap advancement into the upper portion of lip was combined with downward rotation of medial lip. His technique was also revolutionized to preserved Cupid's bow and the suture occupies the place of the filtral column, with formation of the nasal floor and rotation of the base of depressed wing, and in a later stage it corrects the nose by means of the replacement of the cartilages eave. Also it corrects the nasal deformity. It has like problem that the scar of the lip dissuades and deforms the Cupid arc when the cracks are ample, thus is but recommendable its use in incomplete or complete but narrow cleft. Asensio[26] published his technique whose characteristic is the rotation and advance of the filtrum, but difference of the previous ones because he allows the repair of the nasal area in separated form of the lip. This facilitates the manipulation of weaves, which eg: gives to stable results filtrum and proportionate arc of good Cupid, harmonic and symmetrical the nasal wings to equal height.

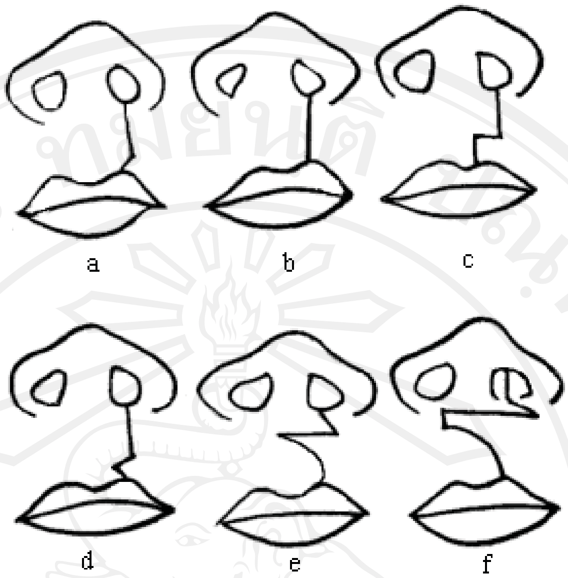


Figure 2.3 Lip repaired techniques illustrated a) Mirault (1884) b) Rose (1891) c) Hagedon-Le Mesurier (1892-1949) d) Tennison (1952) e) Millard (1957) f) Asensio (1971)

2.5 Bone grafting

Problems encountered in the cleft patients are complex. Esthetics is a major concern in cleft patients, Malnutrition is commonly found in cleft patients. Malocclusion is also a routine problem in cleft patient due to midface deficiency, From CT scan study of Weitzman *et al*.[18] shown different in size of upper facial skeleton and maxillary complex between CLP and normal, CLP group observed growth inhibition of upper facial skeletal and of posterior maxillary complex while the mandibles are similar. However, surgery and orthodontic treatment could eliminated this problem. In most cleft patients, bone grafting is one procedure in treatment protocol. The gold bone harvesting site is iliac bone[27]. Bone grafting has become a common procedure in the treatment of cleft lip and palate patients. The main difference in the treatment protocol of the various rehabilitation centers is the timing of the bone graft. According to its time of occurrence, the bone graft may be considered as primary, secondary, or tertiary (late). When performed during early childhood, at the same time as the primary repair surgeries, bone graft is called primary. Some authors stated that this early procedure could cause impairment of maxillary growth. Because of its controversial and counter-productive aspects, this technique was abandoned by most rehabilitation centers that used to perform it.

The lateral incisor was more affected in cleft lip and cleft lip and palate, the second lower premolar was most frequently absent in patients with isolated cleft palate. Brattström and McWilliams[17] investigated dental abnormalities and bone height levels after surgery at three different ages of bone grafting in 202 patients with cleft and found that early secondary bone grafting was performed earlier in patients with hypodontia. The latter strategy also showed the most successful bone height levels. The late secondary bone-grafting group revealed the highest frequency of missing teeth outside the cleft area.[28]

Bone grafting is called secondary when performed later, at the end of the mixed dentition. It is the most accepted procedure and has become a crucial part of the treatment protocol. A secondary bone graft is performed preferably before the eruption of the permanent canine in order to provide adequate periodontal support for the eruption and preservation of the teeth adjacent to the cleft.[29]

When a bone graft is performed at the permanent dentition stage after completion of orthodontic treatment, it is called a tertiary or late graft. The tertiary grafts are performed to enable prosthodontic and periodontal rehabilitation and to assist in the closure of persistent bucconasal fistulae. Nevertheless, tertiary or late bone grafts cannot repair bone loss to the teeth adjacent to the cleft. Occasionally, they cause progressive root resorption on the cervical third.[30]

Success rate of bone grafting was introduced by Bergland *et al*.[31] Which mean infraalveolar bone height classify into 4 grades with respected to optimal height of the interdental bony septum. (Figure 2.4) Type I means alveolar ridge height remained 75-100%, Type II means 50-75% alveolar ridge height remaining, Type III less than 50% and Type IV no continuous bony bridge remaining.

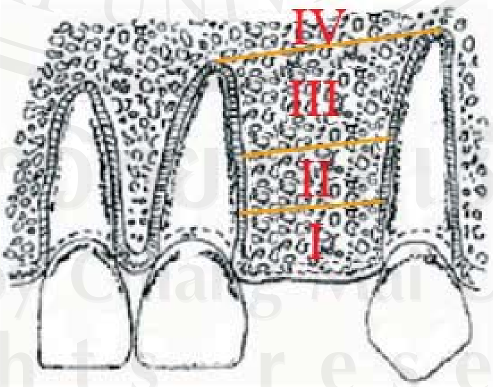


Figure 2.4 Bergland's scale of bone height.

In 1987, Helm *et al*.[32] were the first to develop an objective method of assessing bone graft architecture. They evaluated the bone attachment on the proximal root surface of the central incisor adjacent to the cleft in relation to the length of the anatomic root from the apex to the cementoenamel junction on the periapical radiographs. They also measured the ridge height at the deepest point of the notch in the cleft area in relation to the length of the central incisor. In 1995, Long *et al*.[33] focused on cleft width and canine position as independent variables and measured the level of bone height on the proximal and distal teeth of the cleft defect to evaluate success. By the way, his scale also expresses the area of bone without specifying its position. In this way, most authors reported assessing the bony bridge only on the alveolar side after bone grafting was performed.

Therefore, Witherow *et al*.[34] introduced a new scale for evaluating the position of the bone graft within the cleft. Their scale involved two stages. First, the cleft is bisected vertically by an imaginary line and the roots of the teeth adjacent to the cleft are divided into four. The distal tooth within the cleft could be either the erupted canine or the most distal cleft tooth if the canine was unerupted. Each of the root quarters is allocated a score: 0 when no bone is present from the root surface to the midline of the cleft, 0.5 if some bone is present but fails to reach the midline, and 1 if bone extends from the root surface to midline. The mesial root is expressed, first starting with the apex and moving coronally. This is then repeated with the distal tooth. This culminates in a final 8-point score expressed as a matrix. Then, depending on the positions of the bony bridge spanning the cleft, the radiographs are placed into one of six groups (A to F) that reflect the position of the bone related to the cleft teeth. Category A also requires 75% or more of the root surface to be covered with spanning bone from the cementoenamel junction, and category B at least 25% from the cementoenamel junction. Category C has only 25% of the coronal root deficient of bone, category D, Half of the coronal root deficient of bone. Category E does not have bone bridging at either the apical or the amelocemental levels but has bridging between both the intermediate levels. Category F has 75% or greater of the coronal root deficient in bone. This scale was called Chelsea scale due to they was a Senior House Officer in the Chelsea and Westminster Cleft and Craniofacial Unit.

Norifumi *et al*.[35] suggested that the preoperative condition of periodontal tissue adjacent to the alveolar cleft as well as general and local bone remodeling activity influences the outcome of secondary bone grafting.

Schultze-Mosgua[31] found that resorption in grade 1 is 69%, grade 2 is 19%, grade 3 is 10% and grade 4 is 1%. Thus the overall success rate was 88%.

2.6 Assessment of bone grafting

The two-dimensional (2D) cephalometric analysis was introduced by Broadbent.[36] Since then this method has become one of the most important clinical and research tools in orthodontics and maxillofacial surgery for evaluating craniofacial growth and dentofacial deformities.[37]

Three-dimensional (3D) computed tomography (CT) avoids the superimposition and problems due to magnification and offers the opportunity to evaluate the craniofacial structures in greater detail and with more precision than the 2D method.[38]

There are some problems associated with 3D CT. The high radiation dosage is its main disadvantage (6 rad for an average scan). Therefore, repeated CTs for long-term studies is restricted to cadaver (and possibly animal) studies, although it would be very useful for craniofacial diagnosis and treatment planning. Further problems include high cost, window setting, partial volume effects, spatial uniformity and resolution, artifacts, scan noise, and psychological stress during the procedure (from the patient's side). All these parameters can influence the quality of the CT images and the subsequent 3D reconstructions.[39]

Both 2D and 3D CTs have been used as measuring methods instead of conventional cephalometrics and have been found to be accurate and reliable.[38] Bergland *et al*.[31] studied bone grafting success by using periapical films of 378 patients. Their methods compared radiographs more than 1 year observation. Helms *et al*.[32] reported long term 5 years post surgery of 3 groups of clefts, divided by primary, secondary and tertiary bone graft. Periapical radiographs were evaluated in their study. Their results showed delayed group had a decreased incidence of grafting success compared with the other treatment groups.

Enemark *et al.*[40] also studied long term treatment results after secondary bone grafting in 224 cleft patients with an observation period of more than four years.

Periapical radiographs were evaluated of the treatment results included longitudinal comparison of marginal bone level, periodontal status on cleft-related teeth, dental status in the bone grafted region. They concluded that marginal bone level was higher among unilateral cleft lip and palate and bilateral cleft lip and palate patients in the youngest groups as compared to the older groups.

Long *et al.*[33] used periapical and occlusal radiographs to determine the relationship between the success of secondary alveolar bone grafting and the position of the permanent cuspid relative to the cleft at the time of grafting.

2.7 Factors affecting alveolar bone grafting

Many factors are including alveolar bone grafting success. Bone grafting treatment protocol in cleft patients was to close the oronasal communication, support the soft tissues, restore the alveolar ridge, allow spontaneous eruption of the canine, and avoid prosthetic reconstruction. Three main types of bone graft exist, depending on the time of insertion: primary, secondary, and tertiary bone grafts[41]. Primary bone graft patients received a graft in first two years, with or without presurgical orthopedics. Early secondary bone grafting was grafted before eruption of the canines. Late secondary bone graft patients received a graft after eruption of the canines. Tertiary bone graft patients received a graft in adolescence or adulthood, often in combination with an orthognathic surgery. Early secondary bone grafting is preferred because 80% of the bone reaches a normal level and the canine takes a good position in occlusion[41]. Primary bone grafting usually done in conjunction with maxillary orthopedics to prevention of maxillary arch collapse, migration of teeth into alveolar process, stabilization of premaxilla in bilateral clefts and supporting for alar base[42]. Rib grafts were placed either simultaneously with lip repair or shortly after. Disadvantages of primary bone grafting were the negative effect on maxillary growth and nasolabial appearance and it may necessitate further bone grafting in childhood due to insufficient alveolar bulk.

2.8 Finite element analysis

Finite element method (FEM) is numerical method to solved the engineering problem, such as the structural analysis and heat transfer analysis resulted from stress, loading, heating and the numerical equations are more complex to solved. For example, the analysis automobile parts, trusted bridge and mechanical instrument. According to these complex problems, the simulation numerical was used to solved these problems, and finite element method was one for solved them. Finite element method could estimated the results by divided structure into many elements that have finite number. Each element was calculated in simplex equation and can solved the results of the structure.[43]

In the last decade the application of a well proven predictive technique, originally used in structural analysis, in mechanical engineering, the finite element method (FEM) has revolutionized dental biomechanical research. The technique has been described, in detail, in an early standard text by Zienkiewicz.[44] Basically, the object to be studied is graphically simulated in a computer in the form of a "mesh", which defines the geometry of the body being studied. This mesh is divided, by a process known as discretization, into a number of sub-unit termed "elements". These are connected at a finite number of pointed called "nodes", which are, in turn, defined by their global co-ordinates. The constituent elements are prescribed the appropriate material properties of the structure they represent. What is achieved is a mathematical model of the likely physical response of that object to load; large volumes of information on stresses, strains, and displacement being obtained through the continuum defined.[45]

2.9 Finite element in Dentistry

Early work in this area in orthodontics focused on the development of crude 2D models using existing information on the physical properties of dry/wet bone and other tissues. Inevitably, the validation systems were very limited in scope.[46] Since that time, 3D FEM models of the tooth, periodontal ligament, and bone continuum have been described, a recent example being the work of Nyashin *et al.*[47] Simple time-dependency and visco-elastic properties have also been introduced to make these models more useful in the theoretical analysis of the tissue reaction to orthodontic load McGuinness and Wilson[48], whilst giving the opportunity to examine the important, but often neglected area of tissue strain. Such predictive models have, on occasion, been found to reflect existing, historical experiment data on tooth displacement following load[49], although good useful information is sparse and the methodology employed in collection can often be questioned. However, in any model simulating 'real-life' behavior, an appropriate validation method is essential, to be confident of the accuracy of the results.

In orthodontics, the first finite element article was in Japanese to describe stress in the periodontal tissue at initial phase of various types of orthodontic forces, which then translated to English in the following months.[50,51] Katada *et al*.[52] reported effects of orthopedic headgear and facemask on changes in maxilla in a posterior or anterior direction using the three-dimensional finite element method. Their results showed that posterior force caused a slight posterior displacement and clockwise rotation, while anterior force caused anterior displacement and counterclockwise rotation. Chang *et al*.[53] studied to compare effects of a multiloop edgewise archwire (MEAW) on en masse movement using three dimensional finite element analysis. They found that, compared with a plain archwire, the MEAW showed the discrepancy in the amount of tooth displacement which was lower and individual tooth movement which was more uniform and balanced. These were also minimal vertical displacement or rotation of the teeth using the MEAW archwire. They therefore concluded that the MEAW seemed to have advantages for distal en masse movement of the maxillary dentition. Rudolph *et al*.[54] found that purely intrusive, extrusive, and rotational forces created stresses concentrating at the apexes of roots while bodily and tipping movements created forces concentrating at the alveolar crest. Geramy[55] studied Initial stress produced in the periodontal membrane by orthodontic loads in the presence of varying loss of alveolar bone. Ghosh *et al*.[56] analyzed 6 ceramic bracket designs. They found that designs of the bracket slot and wings for polycrystalline ceramic brackets were good in terms of even stress distribution. The polycrystalline ceramic brackets with an isthmus connecting the wings seemed to resist stresses better than the ones that did not have this feature.

Monocrystalline brackets showed high stress with irregular distribution because of their sharp angles, no rounded corners, or no isthmus.

In finite element analysis, the precision of model construction verifies the predictability as well as the accuracy of the results. To determine the reliability of the model, previous studies compared their calculations with actual measurements made on a living human being. For example, the calculation of stresses at the articular disc of the model have been compared with measured synovial pressure in humans.[57] DeVotch *et al*.[58] also reported an experimental validation of the FEM by performing direct measurement of stresses in the upper compartment of the TMJ in fresh cadaver specimens.

In clefts field, Linping[59] studied alteration in the stress and strain distribution within the maxillary palate, the alveolar arch and the midfacial skeleton. Their results showed that size of the unilateral cleft affects the non-uniformity: the larger the depth and width of the unilateral cleft, the more severe the non-uniform stress/strain distribution within the maxillary palate and midfacial skeleton.