New Classification System for Cleft Alveolus: A Computed Tomography-based Appraisal

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ABSTRACT

Aim: The present study proposed a new classification system based on computed tomography (CT) scan appraisal; this enables the surgeon to identify the extent of the defect and helps to execute the proper treatment plan.

Background: Various terminologies and classifications were proposed to understand developmental defects. But none of the existing classifications/nomenclatures used the preoperative radiographic evaluation (i.e., computed tomography scan—CT scan) in the management and prognosis. Various treatments were advocated and practiced successfully for the surgical correction of lip and palate.

Materials and methods: The available CT scans from archives of the Department of Radiology and Oral and Dental Surgery were evaluated (retrospectively) for cleft alveolus and its morphology as per the proposal. The English language literature was searched in the MEDLINE database without date restriction to revise existing literature on numerous classification systems/nomenclatures using MeSH keywords related to cleft lip, palate, alveolus, developmental disturbance, facial clefts, and classification. Existing classification systems were revisited with a note on the drawbacks. After careful examination of morphological patterns of all clefts, the new CT scan-based alveolar cleft classification is proposed depending on the extent of cleft.

Results: The literature revealed a total of twenty-nine classifications of cleft lip and palate starting from the year 1922 to the year 2015, but none exclusively classified the cleft alveolus based on CT scan observations. The observation of three thousand CT scans showed five types of cleft alveolus, depending on the extent of involvement.

Conclusion: The CT scan-based classification is essential to the surgeon for successful surgical planning of cleft alveolus. The proposed classification is clinically relevant in this digital era for relating surgical outcomes. The three-dimensional viewing of a defect is essential for the surgeon for virtual planning. This paper provides a CT scan-based classification for universal acceptance in this era of digital technology, and CT scan aids in achieving these goals.

Clinical significance: The new proposal is based on preoperative evaluation of cleft using a CT scan. CT scan imaging provides a clear picture of the cleft in three dimensions for the operating surgeon. Advanced technology-enhanced surgical management modalities like CAD/CAM guided templates to support graft for successful management. The classification system will help the medical and surgical fraternity in various aspects. The three-dimensional modeling of defect and printing of a defect model using additive manufacturing technology helps the surgeon for presurgical visualization and virtual planning in a better way. This strategy of defect classification using a CT scan will help obtain better clinical outcomes and patient satisfaction.

Keywords: Alveolus, Anomaly, Cleft, Embryology, Nomenclature, Repair.

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INTRODUCTION

Various classification systems were proposed from the beginning of the era.¹ Many surgeons and clinicians came out with different classification systems. Time immemorial, the classification/nomenclature started with notations so that it can be stored and retrieved digitally.² The wide diversity of cleft lip and palate in terms of clinical presentation makes the universal acceptance of existing classifications difficult,³ and specific cleft alveolus classification does not exist.

The cleft alveolus is an entirely separate entity than a cleft of the palate. It should be viewed in the spectrum of cleft lip.⁴ The existing classifications are either combined with lip, palate, or both, because of the nature of cleft development (Table 1). The isolated occurrence of the cleft alveolus is rare, which might be one of the reasons for not having separate classification. The difference of opinion and need for a universally accepted classification made our team think of a computed tomography (CT) scan-based classification system and factors affecting the prognosis before surgical management. The existing literature proposed many treatment modalities, pre- and postoperative expansion of the maxilla, and schedules for

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Table 1: Existing classification chronologically with comments

<i>S. no.</i>	<i>Proposed by</i>	<i>Year</i>	<i>Comments</i>
1	Davis and Ritchie ⁵	1922	Based on the alveolus, patients with a unilateral or bilateral cleft of the lip and posterior palate with intact cleft alveolus fail to fit into a single group.
2	Victor Veau ⁶	1931	Used incisive foramen as an anatomic landmark for the division of types, but overlooked the cleft patients born with cleft lip, alveolus.
3	Fogh-Andersen ⁷	1946	Based on anatomy and embryology, and the concept of primary and secondary palates involved for grouping.
4	Kernahan and Stark ⁸	1958	Used embryological concepts and primary and secondary palates for description purposes.
5	Vilar-Sancho ⁹	1962	Used Greek nomenclature for classification and coded congenital cleft lip and cleft palate. It could not classify many of the cleft subtypes, even though included alveolus as "G" (gnato) with the right, left, complete, and incomplete. But not adopted worldwide probably because it was in Greek.
6	Harkins et al. ¹⁰	1962	Based on anatomic segmentation into the pre-palate and the palate with subclasses. The subclasses used severity, i.e., quantitative measurement of width and extent of cleft as 1/3, 2/3, or 3/3, but no specific mention of alveolar subclass was made in the classification.
7	Santiago ¹¹	1969	Based on digital and alphabetical notification involved all types for the use of machine coding but not specifically concerning the extent of alveolus as they mentioned either complete or incomplete, unilateral or bilateral.
8	Dahl ¹²	1970	A combination of clefts classification is not possible.
9	Fogh-Andersen ¹³	1971	Modified the original types by adding a new group to feature the median clefts.
10	Kernahan ¹⁴	1971	Described using a Y-shaped diagram representing lip, palate, and alveolus. This notification is merely visual and failed in the application aspect.
11	Elsahy ¹⁵	1973	This is a modified striped Y classification.
12	Spina ¹⁶	1973	Described a modification of terminology in international classification by adding Latin term "foraminal."
13	Balakrishnan ¹⁷	1975	Based on anatomical and embryological representation and was based on Dahl 1970 classification.
14	Sandham ¹⁸	1985	This is modified from Kernahan and Stark.
15	Kriens ¹⁹	1989	Proposed LAHSHAL classification, with acronym lip, alveolus, hard palate, soft palate. The last three words will be for the left side, and the first three words will be for the right side. Because of its verbal communication in different languages its use is limited.
16	Silva Filho et al. ²⁰	1992	Modified Spina classification with the inclusion of group I/III for stratification, but it did not assess cleft severity (cleft size) and the capacity for prognosis estimation.
17	Schwartz et al. ²¹	1993	Proposed an RPL system with numerical coding for easy presentation.
18	Koch et al. ²²	1995	Proposed LAHSN (lip, alveolus, hard and soft palates, and nose) based on the extent in all three directions.
19	Smith et al. ²³	1998	Modified classification of Kernahan striped to compensate for the shortcomings and added additional types. But it did not describe the submucous cleft palate levels nor the alveolus.
20	Ortiz-Posadas et al. ²⁴	2001	Developed mathematical expression for characterization to reflect overall complexity.
21	Castilla and Orioli ²⁵	2004	Presented ECLAMC numerical coding system. This classification presented numerical code for all possible varieties and extent, but did not mention the prognostic factors. It is similar to our presentation, but little variation exists in the use of terminology.
22	Liu et al. ²⁶	2007	Developed (LAPAL system) a five-digit numerical recording system based on Kernahan "Y" classification, Smith-modified Kernahan "Y" classification, and the RPL system. The extent of defects was represented by Arabic numerals (0-4).
23	Koul ³	2007	Used anatomical nomenclature (text) and symbols for proposal. It looks complicated because of the symbols involved in the presentation.
24	Yuzuriha and Muliken ²⁷	2008	Described less form labial clefts with measurements of 3 mm more or less as micro, mini-micro. This presentation includes the operative guide for optimal operative technique depending on the severity of the cleft.
25	Rossell-Perry ²⁸	2009	Proposed classification of severity and diagram for cleft description. Also discussed the selection of proper technique depending on the class of cleft. The severity of the cleft was assessed by the width of cleft and sum of width of the two palatal segments at the junction of soft and hard palates to indicate the tissue deficiency. Based on measurements, the index classifies three degrees of severity for the cleft palate but does not consider alveolus for the same.
26	Khan et al. ²⁹	2013	Revised Smith-modified Kernahan "Y" classification with submucous cleft varieties, but these subclassifications did not consider alveolus.

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S.no	Proposed by	Year	Comments
27	Agarwal ³⁰	2014	Modified Indian classification described by Balakrishnan into groups with a notation of '+' for unilateral and bilateral combinations and abbreviations of the involved part.
28	Luijsterburg et al. ³¹	2014	Based on patho-embryological events like fusion, differentiation, and fusion and differentiation defects of the primary and secondary palates.
29	Allori et al. ¹	2015	Proposed a universal structured form in the form of CLAP notation.

Table 2: Proposed classification for alveolar cleft based on preoperative 3D computed tomography

Class	Description	Nature	Comments	Prognosis
I	One-third alveolus involvement	Submucosal, isolated, unilateral, or bilateral	Tooth involved may be erupted/partially erupted/impacted	Good
II	Two-thirds alveolus involvement	Submucosal, isolated, unilateral, or bilateral	Tooth involved may be erupted/partially erupted/impacted	Good, requires prosthetic or orthodontic treatment
III	Complete alveolus involvement	Isolated, unilateral, or bilateral	Tooth involved may be erupted/partially erupted/impacted	Good, requires prosthetic or orthodontic treatment
IV	Communication with nasal floor	unilateral, or bilateral complete	Tooth involved may be partially erupted/impacted	Depends on the width of cleft and requires prosthetic or orthodontic treatment
V-A	Concomitant with lip and palate	Associated with Class I	Any lip or palate cleft as described previously, might be associated with Class I alveolar cleft	Good with alveolus, but the overall result depends on the associated nature of clefts
V-B	Concomitant with lip and palate	Associated with Class II	Any lip or palate cleft as described previously, might be associated with Class II alveolar cleft	Good with alveolus, but the overall result depends on the associated nature of clefts
V-C	Concomitant with lip and palate	Associated with Class III	Any lip or palate cleft as described previously, might be associated with Class III alveolar cleft	Depends on the width of cleft and the associated nature of clefts and may require a second surgery

alveolar cleft grafting. Grafting of cleft alveolus uses autologous and synthetic bone substitute materials. With our knowledge, none of the published studies have given specific graft material nor advised a standard surgical technique in a particular defect class.

This study proposed a CT scan-based new classification appraisal for cleft alveolus exclusively, after morphological examination of cleft patterns using CT scans (archives of more than 3000 alveolar clefts—both unilateral and bilateral cases) in our center. This study delineates our center management strategy to understand the prognostic factors depending on the new CT-based cleft classification.

MATERIALS AND METHODS

The CT scans of the cleft patients with an age range of 9–20 years from the archives of the Department of Radiology and Oral and Dental Surgery were included for evaluation. The data were evaluated for cleft morphology, and other factors were noted retrospectively to understand the outcomes of surgery. Various cleft defects were appraised and noted as per the new classification. The grafting, defect correction, and its outcomes were noted for surgical emphasis as per our center's protocol based on CT scan.

The English language literature was searched in the MEDLINE database without date restriction to revise existing literature on numerous classification systems using MeSH keywords related to cleft lip, palate, alveolus, developmental disturbance, facial clefts, classification, and nomenclature. Cross-reference search was performed in various plastic and reconstructive journals, head, and neck, oral and maxillofacial journals for comprehensiveness.

RESULTS

The CT scan examination revealed five types of defects. These defects were grouped into five classes, annexed with subclasses (Table 2). The literature revealed a total of twenty-nine classifications/nomenclature of cleft lip and palate since the year 1922 till 2015 (Table 1). Still, none exclusively described cleft alveolus based on CT scan observations.

DISCUSSION

Historically, cleft classification or nomenclature descriptions were given by Davis and Ritchie⁵ way back in the year 1922, followed by many other studies^{1,3,6–31}, as noted in Table 1 with comments. But none of these existing classifications/nomenclatures mentioned cleft alveolus appraisal based on preoperative CT scan examination. The recent explanation of cleft alveolus has noted the historical discrimination of distinguishing it from the palate has not been made clear, which needs to be corrected for proper attention and treatment.⁴ The inadequacies of each classification are mentioned in Table 1 with comments. The advances in radiographic investigations from plain to three-dimensional imaging made the preoperative evaluation and virtual planning more easy and accurate. In the absence of a patient, the surgeon will be able to plan it accurately and discuss with peers before surgery for successful execution as planned using a CT scan.

Proposed Cleft Alveolus Classification

The new classification proposal is based on the preoperative CT scan views of defect patterns and morphology. In the proposed classification, cleft alveolus is divided into five major classes as Class I

to Class V with three subclasses in Class V (Table 2), either unilateral/bilateral depending on the extent of alveolar cleft measuring from the crestal bone of adjacent teeth. The schematic diagram and corresponding representational CT scan images delineate the proposed system of classification for better understanding (Figs 1A to 4A and Figs 1B to 4B). This system considers the depth and width of cleft and thereby helps the operating surgeon for proper planning of the treatment. In concomitant clefts of lip and palate (proposed Class V and its three subdivisions), the surgeon or clinician can adopt any one of the classifications depending on their geography and school of thought for the treatment. Many of our clefts fall in Class V with subclasses; this might require a second surgery for an esthetic correction after the growth of the patient ceases.

The timing for repair of cleft lip and palate were well-established facts in the published literature.^{32–35} The grafting for alveolus was also proposed and practiced widely.^{36–39} But none of the published literature classified cleft alveolus based on preoperative CT scan findings in three dimensions. The advances in diagnostic technology, both prenatal and postnatal, to assess developmental and growth disturbances for predicting anomalies are much better than earlier. Anomaly scanning of parents has

reduced the newer incidence of clefts reasonably. These reducing trends in the defects might be one of the reasons for not having enough number of cases to standardize the existing classification or providing a newer appraisal.⁴⁰ The historical presentations were based on clinical and intraoperative findings. Liu et al.,²⁶ Yuzuriha and Mulliken,²⁷ Rossell-Perry,²⁸ Khan et al.,²⁹ and Agarwal³⁰ classifications have similarities with the proposed classification, but none have a specific description of cleft alveolus using CT appraisal. The present appraisal is distinct and provides better prognostic features. The advances in technology help to create a virtual model for the reconstruction of these defects using CAD/CAM.

Our Center's Protocol for the Management

Description of treatment options as per CT-based classification is as follows:

Classes I and II—use of cancellous alveolar bone grafting, platelet rich fibrin (PRF) membrane placed along the oral surface of the graft. Class III—use of corticocancellous alveolar bone grafting to provide mechanical strength to the graft. PRF membrane was placed along the oral surface of the graft. According to the subdivisions of the proposed classes, the involvement of the nasal floor and depression of the alar base on the affected side(s) should be considered. If the

Figs 1A and B: (A) Schematic diagram and (B) representative 3D CT scan image showing Class I alveolar defect

Figs 2A and B: (A): Schematic diagram and (B) representative 3D CT scan image showing Class II alveolar defect

Figs 3A and B: (A) Schematic diagram and (B) representative 3D CT scan image showing Class III alveolar defect

Figs 4A and B: (A) Schematic diagram and (B) representative 3D CT scan image showing Class IV alveolar defect

nasal floor is involved, an additional PRF membrane has to be placed along the nasal floor mucosa and a thin piece of cortical bone is used to separate the nasal mucosa up to the level of nasal floor, for example, to the same height of the opposite unaffected side in the unilateral cleft. This cortical bone piece acts as resistance while packing the defective area with cancellous bone. The pyriform rim on the affected side[s] in the region of the depressed alar base also needs to be grafted with corticocancellous bone.

Factors Affecting the Prognosis of Cleft Alveolus

The prognosis of cleft alveolus surgery is multifactorial. It can be broadly divided into operator and patient factors. Patient factors include nature and type of cleft. The width of the cleft is considered as one of the critical factors for the success of the graft. Various surgical grafting techniques and adjunct presurgical treatment modalities like naso-alveolar molding for aligning the cleft segments are practiced by clinicians.¹² Grafting strategies of the cleft are well published in the literature.⁴⁰

Limitations of the Study

The study data were collected retrospectively, so the correlations of various factors for the outcome analysis were not considered.

The study also not considered scans of older age-group patients (above 20 years). The surgical modalities are not compared for the esthetic outcome, nor the data available were considered in the surgical and follow-up notes. The prospective study is ongoing to delineate the various factors affecting the prognosis of cleft grafting, taking into consideration new CT scan-based classification. The photographic outcome and patient satisfaction index studies are also ongoing in our center. This is preliminary work on the archival data of CT scan-based morphological examination of the cleft alveolus.

CONCLUSION

The proposed classification is useful for research and clinical purposes. Meticulous planning is required for the successful execution of surgery. By knowing the posterior extent of the cleft in the hard palate using a CT scan, one should be cautious to avoid overpacking of the defect. The new proposal is unique and provides insights into cleft alveolus may be isolated or concomitant. The prognosis of surgery invariably depends on the nature of clefts. It can be used for future reference in systematic reviews. The standardization of defects will provide proper evidence for treatment modalities in this evidence-based digital era.

AUTHOR CONTRIBUTIONS

Philip Mathew and Vivekanand S Kattimani drafted the protocol and developed a search strategy; Team 1, Philip Mathew, Vivekanand S Kattimani, Rahul Vinay Chandra Tiwari, and Team 2, Mohammad Shahid Iqbal, Aisha Tabassum, Khalid Gufran Syed, searched for literature. Vivekanand S Kattimani and Philip Mathew selected articles to include in this analysis. Philip Mathew and Rahul Vinay Chandra Tiwari performed archival data extraction for analysis. Mohammad Shahid Iqbal, Aisha Tabassum, and Khalid Gufran Syed obtained copies of publications of all included studies. Vivekanand S Kattimani and Rahul Vinay Chandra Tiwari extracted data from publications. Mohammad Shahid Iqbal and Aisha Tabassum verified the data entered for review. Vivekanand S Kattimani, Rahul Vinay Chandra Tiwari, and Philip Mathew interpreted the CT scan data; Philip Mathew and Vivekanand S Kattimani drafted the final evaluation and interpretations. All the authors read and approved the final version of the manuscript.

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