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An Evaluation of Conventional Cephalometric Appraisals

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SUMMARY

Although lateral cephalographic diagnosis is central to craniofacial skeletal assessment, their classification (categorization) remains largely empiric. In this study, pre- and post-treatment lateral cephalographic dimensional arrays were subjected to the classic numerical taxonomic technique of cluster analysis. The resultant patient groupings (clusters) were not only inconsistent with respect to their Angle malocclusion categories, but also the composition of each cluster group varies depending upon the dimensional arrays analyzed. These findings demonstrate that lateral cephalometric categorization remains largely subjective.

KEY WORDS:

Lateral Cephalometry, Craniofacial Diagnosis

RÉSUMÉ

Bien que le diagnostic céphalométrique latéral soit essentiel pour l'évaluation du squelette craniofacial, les classifications (catégorisation) restent largement empiriques. Dans le présent travail, les mesures céphalométriques latérales prises avant et après traitement ont été soumises à la technique taxonomique numérique classique de l'analyse de groupe. Les groupes de patients obtenus n'étaient pas compatibles avec leur situation dans la classification des malocclusions d'Angle. De plus, la composition de chaque groupe variait en fonction de l'ordre des dimensions analysées. ces résultats prouvent que la catégorisation céphalométrique latérale reste tout à fait subjective.

MOTS-CLÉS:

Céphalométrie latérale - Diagnostic céphalométrique.

INTRODUCTION

Craniofacial classification (categorization) is the primary focus of orthodontic diagnosis and treatment planning (Sassouni, 1969). Most categories are delineated by relative maxillary to mandibular tooth locations (Neustadt, 1964; Summers, 1971; Freer, 1971; Little, 1975; Richardson, 1981), although skeletal relationships are probably more critically significant. But as study models provide scant information regarding craniofacial skeletal form (Hellman, 1944), craniofacial diagnosis (classification) primarily centers on lateral cephalographic appraisals (Broadbent, 1931). Decisions concerning bilateral bicuspid extractions in Class II malocclusions prior to tooth realignment, therefore, often hinge upon lateral cephalographic categorization (Ingervall et al., 1975). Such categorizations generally involve conscious or subconscious assignments of individual patients to a particular category on the basis of some similar characteristic(s), thereby distinguishing them from others grouped as different categories. Some categories are, however, too generalized to facilitate orthodontic treatment planning (Tuncay and Biggerstaff, 1976). For example, mandibular retrognathism may reflect a short mandible, maxillary prognathism and/or anomalous glenoid fossa or nasion locations. Other categories have more obvious orthodontic connotations indicative of a particular treatment plan, e.g. 'long' and 'short' faces. Additional categories have been described on the basis of more regional facial and/or dental attributes.

Classifically, the anteroposterior maxillary to mandibular first permanent molar relationships define the basic occlusal categories (Angle, 1899, 1907). But as significant patient numbers cannot be assigned to such restricted categories, more complex schemes have subsequently been devised (Simon, 1926; Horowitz et al., 1966). Despite informal augmentations to Angle's categories used by most orthodontists, however, similarly classified malocclusions tend to be treated in a similar manner. But neither malocclusion severity nor complexity can be embraced by the Angle classification scheme or its modifications. Analogous malocclusions may also require quite different therapeutic approaches due to contrasting etiologic factors. In the absence of well-delineated objective criteria, however, more comprehensive classification schemes incorporating various craniofacial malrelationship grades (Ackerman et al., 1969) cannot withstand critical scrutiny.

Yet, the notion that craniofacial (lateral cephalographic) form can be segragated into discrete categories is fundamental to orthodontic diagnosis and treatment planning. But the subjective nature of visual cephalographic assessments necessitates the more objective categorization based on their metrical summaries. The varied correlations between the component cephalometric dimensions (Bjork, 1947; Solow, 1966), however, negate their rigorous categorization on the basis of isolated parameters (Lavelle, 1985). In an attempt to overcome this deficiency, a variety of dimensional constructs have been devised to summarize lateral cephalometric forms (e.g. Downs, 1948; Wylie et al., 1952; Reidel, 1960). Again the component dimensions of such constructs tend to be evaluated in isolation, often relative to 'standard' values (Saksena et al., 1987). Alternative appraisal schemes have been devised, based on both cephalographic and study model parameters. For instance, 33 craniofacial types have been delineated, each corresponding to a specific form of orthodontic treatment (Lavergne et al., 1978, 1982). But the absence of objective discriminatory criteria compromises the validity of such derived craniofacial categories.

Such deficiencies should conceivably be restored if a cephalographic sample, each defined by analogous dimensional arrays, is categorized by a multivariate 'cluster' technique (Cormack, 1971; Gordon and Finden, 1985). Such 'classic' numerical taxonomic approaches (Sneath and Sokal, 1973) have previously been used to segregate ethnic cranial form categories (Sokal et al., 1987), in addition to subdividing Class II malocclusions into five vertical and six horizontal subtypes (Moyers et al., 1980). Unfortunately, the nature of the latter sample precluded investigation of the component facial types in other malocclusion categories. In order to investigate this problem further, the present study was undertaken to examine the various component subgroups (clusters) delineated for a patient sample before and after orthodontic treatment on the basis of their lateral cephalographs. The prime objective of this study therefore focussed on the significance of traditional Angle categories for the delineation of lateral cephalometric form before and after orthodontic treatment.

MATERIALS AND METHODS

This retrospective study was based on lateral cephalographs of 41 patients aged 13-17 years taken just prior to (A records) and following the completion (D records) of orthodontic treatment taken under standard conditions including a cephalostat. The cephalographs were selected from an initial much larger sample, the primary criterion being image clarity to facilitate datum point identification. In addition, the pre-treatment cephalographs, and associated study models, were carefully scrutinized to ensure that the patients could be unequivocally assigned to one of the Angle Class I, II division 1 or II division 2 categories on the basis of the criteria defined by Beresford (1969). Furthermore, based on the criteria defined by Ballard (1956), patients categorized as Angle Class I or II malocclusions were further selected so their maxillo-mandibular skeletal categories were respectively Class I and II.

The cephalographic outlines were then delineated by 33 traditional datum points, as described by Cleall and Chebib (1971) (Fig. 1). Following orientation on the Frankfort horizontal plane and registration on sella point, the datum point Cartesian (x and y) coordinates were delineated using a graphics tablet. Cephalometric form of each patient before and after orthodontic treatment were ultimately delineated by 152 linear and angular dimensions spanning the various datum points. To simplify this study, cephalometric summaries were also provided by the following conventional appraisal techniques: Tweed (Tweed, 1946), Steiner, 1953), Holdaway, 1956), Downs (Downs, 1952), Ricketts (Ricketts, 1957),

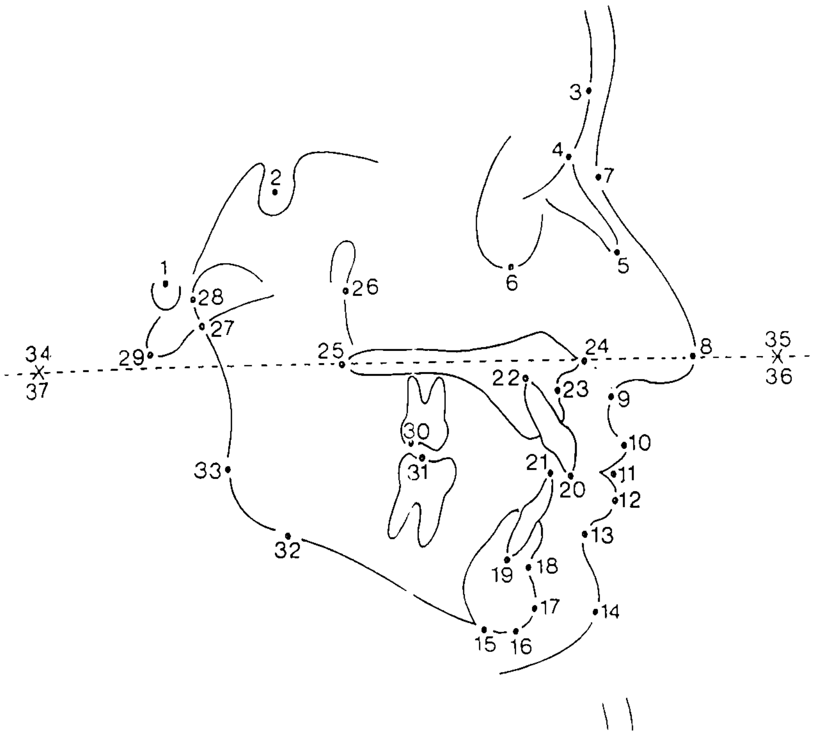

Fig. 1: Datum points defining lateral cephalographic form (Enlow, 1982).

Sassouni, 1955) and Manitoba (Cleall and Chebib, 1971) analyses.

These before and after orthodontic treatment cephalometric dimensions were then subjected to agglomerative hierarchical cluster analysis (Everitt, 1980). The analyses proceeded by a series of steps in which each patient (characterized by a particular cephalometric dimensional array) was progressively grouped together into a series of larger clusters. Individual patients were therefore clustered together only if their component cephalometric dimensins added the least to the within group variability. Such a cluster analysis (Ward, 1963) defined the distance between all individual patient pairs within the groups. At any stage in the analysis, therefore, the information loss resulting from grouping individual cephalometric forms into clusters could be measured by the total sum of squared deviations of every point from the mean of the cluster to which it belonged. In addition, union of every possible cluster pair was considered at each step in the analysis, with a cluster pair being combined only where fusion resulted in the minimum increase in the error sums of squares (Gower, 1967).

In this study, the cephalometric dimensional arrays were subjected to Ward's cluster analysis contained in CLUSTAN, the cluster analysis package devised by Wishart (1987). Ultimately, therefore, these cluster groupings were compared for the patients before and after orthodontic therapy, based on a variety of cephalometric arrays. In addition, the cephalometric dimensions of the individual patients contained within each significant cluster group of the original sample were subjected to a step-wise discriminant analysis (Lachenbuch et al., 1979). This latter statistical test was performed to ensure that each of the derived subgroups from the original sample were, in fact, discrete.

RESULTS

When the pre-treatment cephalometric dimensions of the Tweed analysis were subjected to cluster analysis, 3 significant cluster groups were evident, comprising 15, 11 and 21 patients respectively (Fig. 2). But each of these cluster groups were heterogeneous relative to their Angle categories. For instance, the first cluster group contained 15 patients (40% Class I, 53% Class II division 1 and 7% Class II division 2) whereas the second group of 11 patients comprised 73% Class II division 1 and 27% of Class II division 2 patients. Thus the 3 cluster groups exhibited no consistent relationship to their compo-

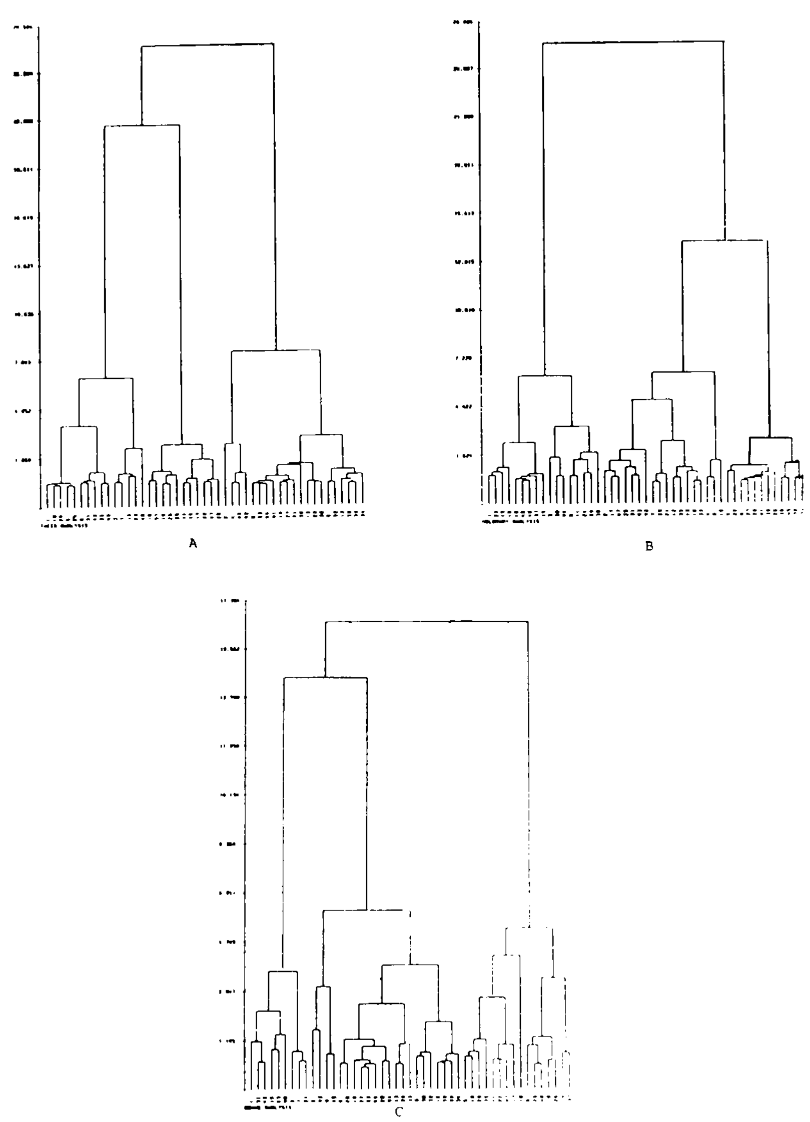

Fig. 2: Dendograms based on cluster analyses of the parameters derived from conventional pre-treatment cephalometric appraisals.
A = Tweed, B = Holdaway, C = Downs' appraisals.

nent Angle categories when based on pre-treatment (A) Tweed cephalometric appraisals. This inconsistency was illustrated by patients identified as 'nearest neighbours' on the dendrogram, e.g. patients 16 and 20 were Class II division 1 and Class 1 patients respectively and so were quite dissimilar. Analogous results similarly emerged from subjecting the parameters of the other traditional cephalometric appraisals to cluster analysis, i.e. the Downs, Steiner, Holdaway, Ricketts, Manitoba and Sassouni appraisals, in addition to analysis of either all the linear or angular dimensions subtended by the cephalometric datum point arrays for the same patient sample. Thus, although three significant cluster groups were consistently delineated in each analysis, each cluster group was shown to be markedly heterogenous relative to their patient Angle categories (Table I). These cluster analyses therefore indicated that pre-treatment patient categorization on the basis of their Angle categories was inconsistent with their classification based on their lateral cephalometric appraisals. In addition, objective pre-treatment lateral cephalometric appraisals showed varying patterns of categorization depending upon the parameters included in the analysis, i.e. conflicting patient categorization emerged depending on the specific form of cephalometric appraisal utilized.

Analogous findings also emerged from taxonomic classifications based on the various post-treatment

Table I
Cluster group composition based upon cephalometric evaluations *before* and *after* orthodontic treatment

Analysis		Cluster Group 1	Cluster Group 2	Cluster Group 3
Tweed	Before	15 (40 % I, 53 % II_i, 7 % II_{ii})	11 (73 % II_i, 27 % II_{ii})	21 (18 % I, 62 % II_i, 10 % II_{ii})
	After	11 (45 % I, 36 % II_i, 18 % II_{ii})	14 (21 % I_i, 64 % II_i 14 % II_{ii})	22 (18 % I, 73 % II_i, 9 % II_{ii})
Steiner	Before	21 (33 % I, 62 % II_i, 5 % II_{ii})	13 (31 % I_i, 54 % II_i 15 % II_{ii})	13 (8 % I, 69 % II_i, 23 % II_{ii})
	After	22 (23 % I, 68 % II_i, 9 % II_{ii})	7 (29 % I_i, 43 % II_i 29 % II_{ii})	18 (28 % I, 61 % II_i, 11 % II_{ii})
Ricketts	Before	15 (33 % I, 47 % II_i, 20 % II_{ii})	19 (21 % I_i, 63 % II_i 16 % II_{ii})	13 (23 % I, 77 % II_i)
	After	8 (50 % I, 25 % II_i, 25 % II_{ii})	18 (17 % I_i, 78 % II_i 6 % II_{ii})	21 (24 % I, 62 % II_i, 14 % II_{ii})
Sassouni	Before	9 (33 % I, 56 % II_i, 11 % II_{ii})	17 (41 % I_i, 35 % II_i 24 % II_{ii})	21 (10 % I, 86 % II_i, 5 % II_{ii})
	After	9 (22 % I, 67 % II_i, 11 % II_{ii})	16 (31 % I_i, 50 % II_i 19 % II_{ii})	22 (23 % I, 68 % II_i, 9 % II_{ii})
Holdaway	Before	16 (19 % I, 69 % II_i, 13 % II_{ii})	19 (21 % I_i, 63 % II_i 16 % II_{ii})	12 (42 % I, 50 % II_i, 8 % II_{ii})
	After	12 (17 % I, 75 % II_i, 8 % II_{ii})	20 (25 % I_i, 65 % II_i 10 % II_{ii})	16 (31 % I, 50 % II_i, 19 % II_{ii})
Downs	Before	9 (44 % I, 33 % II_i, 22 % II_{ii})	22 (27 % I_i, 64 % II_i 9 % II_{ii})	16 (8 % I, 75 % II_i, 8 % II_{ii})
	After	11 (27 % I, 42 % II_i, 27 % II_{ii})	17 (29 % I_i, 65 % II_i 66 % II_{ii})	19 (21 % I, 68 % II_i, 11 % II_{ii})
Manitoba	Before	15 (20 % I, 80 % II_i)	18 (33 % I_i, 61 % II_i 6 % II_{ii})	14 (21 % I, 43 % II_i, 36 % II_{ii})
	After	32 (25 % I, 72 % II_i, 3 % II_{ii})	7 (14 % I_i, 43 % II_i 43 % II_{ii})	7 (43 % I, 43 % II_i, 14 % II_{ii})
Lengths	Before	15 (20 % I, 80 % II_i)	7 (14 % I_i, 43 % II_i 43 % II_{ii})	7 (43 % I, 43 % II_i, 14 % II_{ii})
	After	32 (25 % I, 72 % II_i, 3 % II_{ii})	7 (14 % I_i, 43 % II_i 43 % II_{ii})	7 (43 % I, 43 % II_i, 14 % II_{ii})
Angles	Before	24 (25 % I, 54 % II_i, 21 % II_{ii})	8 (13 % I_i, 75 % II_i 13 % II_{ii})	15 (33 % I, 67 % II_i)
	After	22 (23 % I, 68 % II_i, 9 % II_{ii})	12 (33 % I_i, 50 % II_i 17 % II_{ii})	13 (23 % I, 62 % II_i, 15 % II_{ii})

NB: Within each cluster group, the number of patients is listed, with the composition relative to their Angle malocclusion category listed in brackets.

(D record) lateral cephalometric appraisals (Table I). Thus, although three cluster groups from within the same patient sample were consistently delineated, their composition varied depending upon the parameters actually included in the analysis (Fig. 3). For instance, 11 patients comprised the first cluster group based on the post-treatment Tweed analysis, 22 on the Steiner analysis and 32 on the Manitoba analysis. More importantly, the actual patients included in the various cluster groups were not consistent between the various appraisal techniques. For instance, the 9 patients included in the first cluster group on the Sassouri analysis were not included in the 32 patients of the first cluster group from the Manitoba analysis. These results therefore suggested that Angle's categories, or traditional methods of lateral cephalometric appraisal, were of little value in segregating patients either before or after treatment.

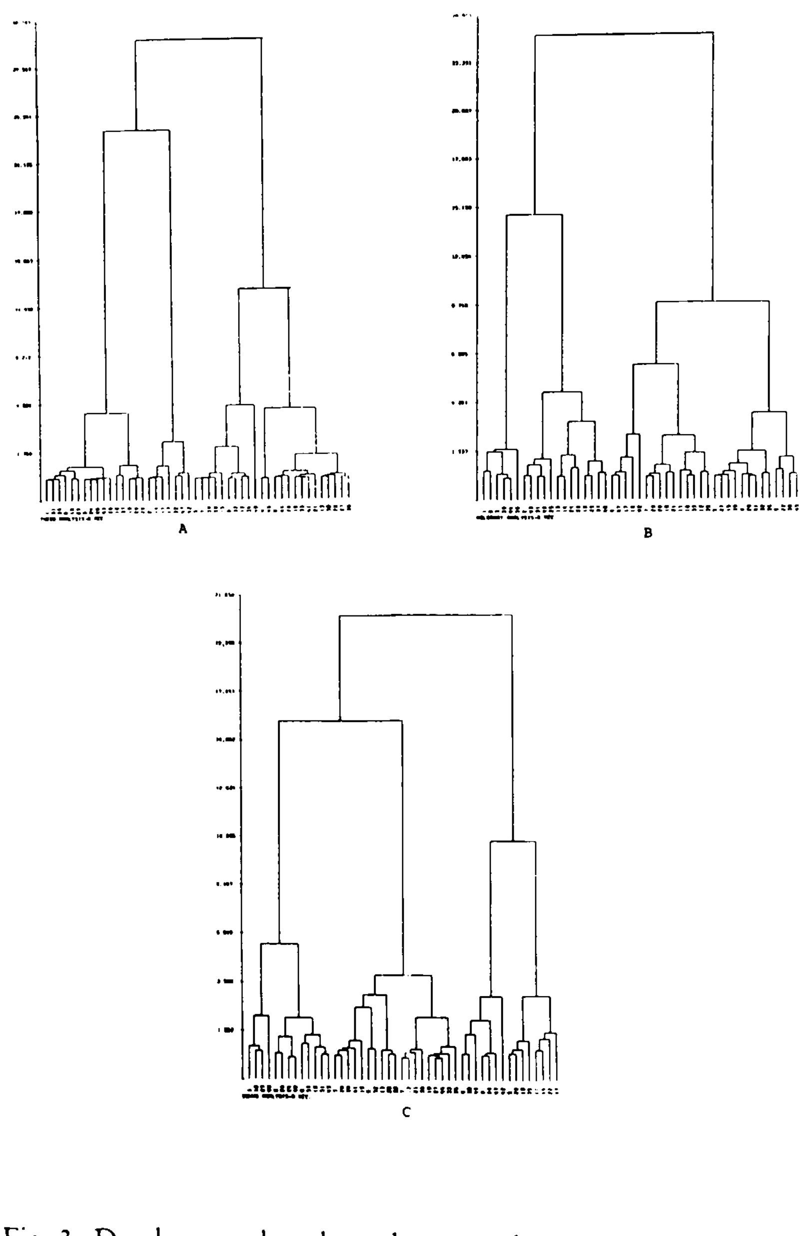

Fig. 3: Dendograms based on cluster analyses of the parameters derived from conventional post-treatment cephalometric appraisals.
A = Tweed, B = Holdaway, C = Downs' appraisals.

These findings were subsequently confirmed by sequential step-wise discriminant analyses. Thus, although the three cluster groups derived from each of the various cephalometric appraisals were shown to be statistically discrete, no one specific dimension(s) was shown to contribute more significantly than others to the inter-cluster group discrimination. Thus the results of this study not only indicated that the parameters derived from various cephalometric appraisals provided no consistent pattern of patient categorization before (A records) or after (D records) treatment, but also that the various Angle malocclusion categories have scant correlation with cephalo-metric form.

DISCUSSION

Accurate diagnosis hinges on separating component craniofacial problems and synthesizing their potentially disparate solutions into unified overall treatment strategies (Dockrell, 1952; Rinchuse and Rinchuse, 1989). Although lateral cephalographic appraisal is generally considered essential in this regard, however, their relative importance to other diagnostic aids (e.g. study models or previous cephalometric appraisals) will vary between particular patients. As 'normal' maxillary to mandibular occlusal relationships may occur with underlying jaw discrepancies, or significant malocclusions with 'normal' anteroposterior skeletal patterns, lateral cephalometric appraisals are often regarded as central to orthodontic diagnosis and treatment appraisal.

Most lateral cephalographic categorization schemes may, however, be criticized on the basis of their narrow focus, i.e. excluding potentially significant diagnostic features (e.g. the temporomandibular joint) (Ackerman and Proffit, 1969). For instance, one method of cephalometric appraisal centers on comparisons of individual dimensions relative to 'standards' (Saksena et al., 1987). But such 'standards' are generally based on limited samples, without guidance being provided as to whether specific dimensions should differ more than 1, 2 or 3 standard deviations from the 'standard' to be regarded as 'abnormal'. Also, although many geometric constructs have been devised to summarize lateral cephalometric form (Harvold, 1974; Jacobson, 1975; Ricketts, 1981; McNamara, 1983), there is no concensus as to which is most appropriate for patient categorization or assessment (Moyers and Bookstein, 1979; Richtsmeier and Cheverud, 1986).

This was confirmed by the present study, where no consistent pattern of patient categorization emerged when based on various forms of lateral cephalometric appraisal. These data confirmed the results of others, who have noted variable correlation between lateral cephalometric dimensions of Class I and II malocclusions (Renfroe, 1945; Anderson and Popovich, 1989).

There are also more fundamental concerns regarding lateral cephalometric descriptions (Moyers et al., 1979). In addition to comprising two-dimensional images of complex three-dimensional craniofacial forms, there has been growing debate as to the validity of conventional cephalometric appraisals. For instance, conventional cephalometric techniques hinge on the registration of cephalographs relative to a point (commonly sella point) and their relative plan at orientation (Frankfort or mandibular plane). But more recent evidence suggests that such points and planes are not as stable as traditionally envisaged (Enlow, 1982; Latham, 1972; Richtsmeier and Cheverud, 1986). Also complex, rather than simple linear, trajectories emerge from sequential lateral cephalometric comparisons (Walker and Kowalski, 1972). Furthermore, in addition to the component cephalometric dimensions being variably together (Solow, 1966), linear or angular dimensional changes provide scant information regarding the specific datum points responsible for a dimensional change. Yet alternative, potentially more rigorous, techniques, e.g. finite element analysis (Moss et al., 1985), require further evaluation before being shown to have direct clinical application. Thus, the results of this study indicated that conventional appraisal techniques are insufficient for objective cephalometric diagnosis (classification), i.e. other diagnostic data are imperative for unequivocal patient categorization.

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