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Validity of Three Cephalometric Analyses for Diagnosis of the Anteroposterior Postion of the Maxilla

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"VALIDITY OF THREE CEPHALOMETRIC ANALYSES FOR DIAGNOSIS OF THE ANTEROPOSTERIOR POSTION OF THE MAXILLA"

by:

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Validity of three cephalometric analyses for diagnosis of the anteroposterior position of the maxilla

Abstract

Purpose: The purpose of this investigation was to investigate the validity of 3 different cephalometric analyses used for diagnosis of the anteroposterior (AP) position of the maxilla. **Methods:** Retrospective data including a pre-treatment cephalometric radiograph, repose and smiling profile photographs, and a clinically determined upper incisor to Glabella Vertical (GV) measurement were collected from 30 consecutive patients. Photographs were deidentified with eye coverage and presented in survey form to groups of orthodontists and oral surgeons who judged the maxillae as prognathic, orthognathic, or retrognathic. Corresponding cephalometric radiographs were evaluated using McNamara, Steiner, and GV analyses. Cephalometric diagnoses and clinical impressions were compared to determine which analysis correlated best with clinical impressions. **Results:** There was a difference between clinical impressions of the AP position of the maxilla in smiling and repose profiles. There was a difference in diagnosis of AP position of the maxilla using the Steiner, McNamara and GV analyses. There was a correlation between clinical impression of repose profiles and diagnosis with the Steiner analysis. There was a correlation between clinical impression of smiling profiles and diagnosis with the GV analysis. **Conclusions:** Both repose and smiling profiles should be evaluated for comprehensive orthodontic treatment planning. The Steiner and GV analyses are useful tools for diagnosing the AP position of the maxilla on a cephalometric radiograph. Cephalometric analysis using GV may be a more valid analysis due to its superior correlation with clinical impressions of smiling profiles.

Introduction

Classic cephalometric analyses exist to evaluate soft tissue, skeletal and dental relationships for individual patients, as compared to population norms. These analyses utilize hard and soft tissue landmarks and referents found on cephalometric radiographs and compare values of measured angles and lineations to normative values in set populations.[1] The landmarks used are often highly variable and subject to identification error and therefore inherently unreliable.[1,17] Intracranial reference lines such as Frankfort Horizontal (FH) and Sella-Nasion (S-N) have been particularly criticized for extensive variability to a true horizontal plane.[6,17] Extracranial references have been suggested as more reliable replacements for the generally accepted intracranial reference lines that bolster classic cephalometrics.[6]

One such extracranial referent, Glabella Vertical (GV), establishes a patient in natural head position (NHP) and drops a vertical line from an easily identifiable point on the forehead.[5] NHP is proven as a repeatable and reliable position directed by clinicians that represents the true-life appearance of the patient.[7,16] Madsen et al confirmed that a true vertical or horizontal plane from NHP is the most valid craniofacial reference.[8] Multiple authors have determined that small differences in registering NHP were of negligible concern compared to the inherent variation of intracranial reference lines.[7,17] The forehead has been established as a useful landmark due to its minimal change during growth, further supporting the use of GV as a referent.[5]

Use of GV in cephalometric analysis is derived from the concept introduced by Andrews in his Six Elements of Orofacial Harmony™. Andrews defines an Element I maxillary incisor as optimal when the inclination of the facial axis of the crown is 7 degrees to the occlusal plane, and its root is centered facio-lingually in bone.[2] Cephalometric analysis using GV preserves the concepts of the Element I incisor and identifies ideal facial esthetics when the FA point of the optimally inclined maxillary incisor is coincident with GV. In this manner, the AP position of the maxilla can be evaluated by identifying the Element I incisor on a cephalometric radiograph and measuring its position – either behind, coincident with, or forward of GV.[5] O'Donovan et al mandated that facial harmony exists only when the maxillomandibular complex is in an optimal relationship to the position of the forehead, providing additional relevance to the use of the GV analysis.[9] Resnick et al described a preference among oral surgeons for the Andrews analysis over standard cephalometric analysis in treatment planning for orthognathic surgery.[11]

The Steiner Analysis uses an angular measurement between Sella-Nasion and Nasion-A point to diagnose the AP position of the maxilla. The Caucasian norm is 82 degrees, and the accepted standard deviation is +/- 3.5 degrees. The McNamara Analysis establishes a vertical line through Nasion that is drawn perpendicular to Frankfort Horizontal, defined as Porion-Orbitale. A linear measurement is then drawn from Nasion-Perpendicular to A point to diagnose the AP position of the maxilla. The Caucasian norm is 0mm, and the accepted standard deviation is +/- 2mm. The Glabella Vertical Analysis relies on a vertical line drawn through Glabella in conjunction with a clinically determined measurement from that line to the FA point of the most anteriorly placed upper central incisor. The clinically determined GV measurement establishes the vertical referent and is used to orient the cephalometric radiograph, but definitive diagnosis with the GV analysis is calculated after uprighting of the central incisor. The central incisor is uprighted to an ideal inclination of 7 degrees from the facial axis to the occlusal plane and centered in bone, as defined by Element II in the Andrews 6 Keys of Optimal Occlusion. The Caucasian norm is 0mm, and the proposed standard deviation is +/- 1mm.

Diagnoses determined from cephalometric analyses often do not correlate with clinical impressions of malocclusions.[10] Adams et al described the inconsistencies between hard tissue structures and the overlying soft tissue, which likely contributes to the discrepancy between cephalometric analysis and clinical impressions.[1] In fact, Schlosser et al demonstrated that good facial harmony exists within a wide range of cephalometric values.[15] Multiple authors have reported that orthodontic treatment that adheres strictly to cephalometric norms does not necessarily yield optimal facial esthetics.[4,10,14] Similarly, Resnick et al found that cephalometric analyses had limited use in treatment planning the sagittal position of the maxilla for orthognathic surgery.[11] Tourne et al suggested that dental professionals rely more on their clinical impressions than cephalometric diagnoses.[16]

GV is a clinically determined measurement that can also be used to evaluate the position of the maxillary central incisor to the forehead in a smiling profile.[3] Orthodontic records routinely include frontal facial photographs and a profile photograph in repose, but multiple studies have highlighted the advantage of addition of a smiling profile photograph to diagnostic records to fully evaluate for facial esthetics while treatment planning orthodontic cases.[4,5] While there are many studies that document a difference between underlying hard tissue anatomy and overlying soft tissue drapes, there is a lack of investigation into the difference in clinical impressions of smiling and repose profiles.

Clinical impressions of orthodontists and oral surgeons were of particular interest in this study due to their specialized training in the evaluation of facial esthetics. Romani et al reported that orthodontists and oral surgeons use cephalometric analysis plus subjective clinical judgement to treatment plan, and that their judgements may be more discerning than those of laypeople.[13] Resnick et al reported that oral surgeons preferred Andrews analysis over standard cephalometric analysis when treatment planning orthognathic surgical movements for the sagittal position of the maxilla.[11]

There is currently no "gold standard" for diagnosis of the anteroposterior position of the maxilla.[12,18] The purpose of this study was to evaluate for a correlation between clinical impression and cephalometric diagnosis of the anteroposterior position of the maxilla. Findings from this study may elucidate a more superior method for assessment of the anteroposterior position of the maxilla. The null hypotheses were: 1) there is no difference in the judged AP position of the maxilla using repose and smiling profile photographs, 2) there is no difference between cephalometric diagnosis of the AP position of the maxilla using the Steiner, McNamara and GV analyses, and 3) there is no correlation between clinical judgement of repose and smiling profile photographs and cephalometric diagnosis of the AP position of the maxilla.

Materials and Methods

Retrospective data from 30 consecutive Caucasian patients was collected from initial records in the Department of Orthodontics at the Medical University of South Carolina. Initial diagnostic records included a cephalometric radiograph, repose and smiling profile photographs with the subject in adjusted natural head position, and a clinically determined upper incisor to Glabella Vertical measurement. The GV measurement was visually determined by an experienced orthodontist and confirmed with a measurement device comprised of a horizontal millimetric ruler set to Glabella, a pointer set to the FA point of the most anteriorly positioned upper central incisor, and a level used to confirm accurate placement of the device. A second orthodontist recorded a clinical GV measurement for all patients to confirm reliability of the measurement.

Subjects were classified as having negative GV measurements if the value was less than -1mm, neutral GV measurements if the value was more than -1mm but less than +1mm, and positive GV measurements if the value as greater than +1mm. The first 10 Caucasian patients in each group identified as having negative, neutral and positive GV values respectively were enrolled in the study, comprising a total of 30 subjects. Caucasian patients with complete records, as previously described, met the inclusion criteria. Records of patients with craniofacial anomalies, histories of trauma or orthognathic surgery, and non-Caucasian ethnicities were excluded. Of the 30 enrolled subjects, 5 female and 5 male subjects were included in the GV negative and GV neutral groups. In the GV positive group, there were 2 male subjects and 8 female subjects. A power analysis using results from prior similar studies determined that a study group of 30 subjects would yield significant results. This study was approved as Exempt by the IRB-II committee at the Medical University of South Carolina.

The repose and smiling profile photographs were deidentified with eye and eyebrow coverage and conversion to black and white to minimize potential bias (Figure 1). The repose and smiling photographs were randomized in a REDCAP survey, and the survey was sent to orthodontists and oral surgeons, who had no prior knowledge of the study hypotheses. The survey asked for the dental specialist to identify themselves as an orthodontist or an oral surgeon and then to designate the maxilla in each of the 60 photographs as retrognathic, orthognathic, or prognathic. A total of 22 oral surgeons and 77 orthodontists responded to the survey.

The 30 cephalometric radiographs were hand traced in Microsoft PowerPoint™ by a single operator using a calibrated digital millimetric ruler and a digital protractor. More than one month later, the same operator repeated all measurements on 10 of the 30 radiographs to evaluate intrarater reliability. A second operator also repeated measurements on the same 10 radiographs to evaluate interrater reliability. On each radiograph, Glabella, Sella, Nasion, Porion, Orbitale, and A point were identified, and the Steiner, McNamara and Glabella Vertical cephalometric analyses were calculated to diagnose the maxilla as retrognathic, orthognathic, or prognathic (Figure 2).

Diagnosis of the AP position of the maxilla from the three cephalometric analyses was compared to the clinical impressions by orthodontists and oral surgeons of the repose and smiling profile photographs. Statistics were run by the Division of Population Oral Health at the James B. Edwards College of Dental Medicine. Cohen's kappa (κ) was calculated to determine the amount of agreement or disagreement between all variables. Cohen's kappa values represent the following degrees of agreement: ≤0 disagreement, 0.01-0.20 poor or chance agreement, 0.21-0.40 slight agreement, 0.41-0.60 fair agreement, 0.61-0.80 good agreement, 0.81-0.92 very good agreement, 0.93-0.99 excellent agreement, and 1.00 perfect agreement. Descriptive statistics were run to determine if a difference existed between some variables. Differences were considered significant if $P<0.05$.

Figure 1. Orthodontists and oral surgeons judged the AP position of the maxilla in repose and smiling profiles as prognathic, orthognathic or retrognathic.

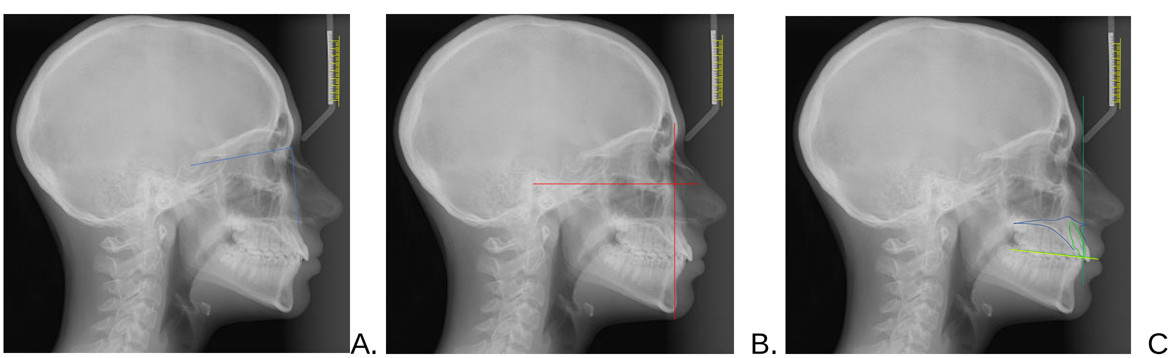

Figure 2. Cephalometric radiographs, traced with SNA, A-NPerp, and GV, respectively, to determine cephalometric diagnosis of the AP position of the maxilla.

Results

Clinical impression of the AP position of the maxilla in repose and smiling profiles by all judges for all subjects agreed 74% of the time, demonstrating fair agreement using Cohen's kappa value (κ=0.4474). (Table 1) Judgement of AP maxillary position of female subjects was consistent 71% of the time (κ=0.32), indicating slight agreement between judgement of the repose and smiling profiles. (Table 2) Judgement of male subjects demonstrated fair agreement (κ=0.60), with clinical judgements of repose and smiling profiles agreeing 80% of the time. (Table 3).

Orthodontists yielded fair agreement in their judgements of each subject's smiling and repose profiles, with consistent judgements 79% of the time (κ=0.5758). (Table 4) Orthodontists judged the repose and smiling profiles consistently in 72% of the female subjects (κ=0.47), indicating fair agreement, and in 80% of the male subjects (κ=0.62), indicating good agreement. (Tables 5 and 6)

Oral surgeons were less consistent in their judgements of repose and smiling profiles, showing only slight agreement (κ=0.3304) in 64% of subjects. (Table 7) Oral surgeons judged the repose and smiling profiles consistently in 65% of the female subjects (κ=0.29) and 75% of the male subjects (κ=0.3, indicating only slight agreement for both sexes. (Table 8 and 9)

Judgements by orthodontists agreed more frequently with the majority for repose profiles (90%) and smiling profiles (83.33%) compared to judgements by oral surgeons (73.33%), though this finding was not statistically significant (p-value=0.6274). (Table 10)

Clinical GV measurements were recorded by two operators and were considered consistent if they differed less than 1mm. Interrater reliability for the clinically repeated GV measurements was 90% (correlation=0.95). (Table 11)

There was a statistically significant difference in the diagnosis of the AP position of the maxilla using GV, Steiner and McNamara analyses (p-value<0.0001). (Table 12) Steiner and McNamara analyses showed 50% agreement in diagnosis of the AP position of the maxilla (κ=0.09). (Table 13) GV and Steiner analyses showed 36% agreement (κ=0.04), whereas GV and McNamara analyses showed only 27% agreement (κ=-0.12). (Tables 14 and 15) Cohen's kappa values for comparison of Steiner and McNamara analyses, and GV and Steiner analyses both indicated poor or chance agreement. Cohen's kappa value for GV and McNamara analyses indicated no agreement.

Intrarater reliability for the cephalometric analyses showed good agreement for Steiner (κ=0.7826), very good agreement for GV (κ=0.8305), and perfect agreement for McNamara (κ=1.00). (Tables 16, 17 and 18) Interrater reliability for the cephalometric analyses yielded perfect agreement for GV and McNamara (κ=1.00) and fair agreement for Steiner (κ=0.59). (Tables 19, 20 and 21)

There was a correlation between clinical judgement and cephalometric diagnosis of the AP maxillary jaw position using GV and Steiner analyses. Clinical judgement of the repose profiles correlated best with cephalometric diagnosis using the Steiner analysis (59%, κ=0.19), closely followed by the GV analysis (48%, κ=0.15). Clinical judgement of the smiling profile correlated best with cephalometric diagnosis using the GV analysis (54%, κ=0.19). These Cohen kappa values, however, demonstrated poor or chance agreement. Notably, cephalometric diagnosis with the McNamara analysis showed no agreement between clinical judgements of repose and smiling photographs (κ=-0.13 and -0.14, respectively). (Table 22)

There was a greater correlation of clinical judgement of repose profiles with cephalometric diagnosis using the Steiner analysis in females (68%, κ=0.20). There was a greater correlation of clinical judgement of repose profiles with cephalometric diagnosis using the GV analysis in males (60%, κ=0.38). Cohen's kappa value for this agreement in females indicated poor or chance agreement, while the kappa value for males indicated slight agreement. (Table 23)

There was slightly greater correlation of clinical judgement of smiling profiles with cephalometric diagnosis using the Steiner analysis in females (53%, κ=0.21), but was closely followed by GV and McNamara analyses (κ=0.19). Despite the similar kappa values, diagnosis with Steiner yielded fair agreement, while diagnosis with GV and McNamara yielded poor or chance agreement with smiling profiles in females. There was a greater correlation of clinical judgement of smiling profiles with cephalometric diagnosis using the GV analysis in males (63%, κ=0.27), indicating slight agreement. (Table 24)

Clinical judgement by orthodontists was most closely associated with cephalometric diagnosis using the Steiner analysis for repose profiles (59%, κ=0.13), although the kappa value indicated poor or chance agreement. Clinical judgement of smiling profiles by orthodontists demonstrated fair agreement with cephalometric diagnosis using the GV analysis (55%, κ=0.22). (Table 25) Clinical judgement by oral surgeons correlated best with cephalometric diagnosis using the Steiner analysis for repose profiles (64%, κ=0.24) and the GV analysis for smiling profiles (63%, κ=0.33). Both of these kappa values indicated slight agreement. (Table 26)

Table 1. Assessments of all smiling and repose profiles from all judges agreed 74% of the time.

κ= 0.4474 (74% agreement)				
Majority Smile	**Majority Repose**			
	Orthognathic	**Prognathic**	**Retrognathic**	**Total**
Orthognathic	15	0	1	16
Prognathic	0	1	0	1
Retrognathic	6	0	4	10
Total	21	1	5	27

Table 2 and 3. In females, judgements of repose and smiling profiles agreed 71% of the time. In males, there was 80% agreement of repose and smiling judgements.

Female κ=0.32 (71% agreement)				
Majority Smile	**Majority Repose**			
	Orthognathic	**Prognathic**	**Retrognathic**	**Total**
Orthognathic	10	0	1	11
Prognathic	0	1	0	1
Retrognathic	4	0	1	5
Total	14	1	2	17

Male κ=0.60 (80% agreement)			
Majority Smile	**Majority Repose**		
	Orthognathic	**Retrognathic**	**Total**
Orthognathic	5	0	5
Retrognathic	2	3	5
Total	7	3	10

Tables 4, 5 and 6. Orthodontists were consistent in their judgements of repose and smiling profiles 79% of the time. For female subjects, orthodontists demonstrated 72% agreement. Orthodontists showed 80% agreement in males.

κ=0.5758 (79% agreement)				
Ortho Smile	**Ortho Repose**			
	Orthognathic	**Prognathic**	**Retrognathic**	**Total**
Orthognathic	15	1	0	16
Prognathic	0	1	0	1
Retrognathic	5	0	6	11
Total	20	2	6	28

Female κ=0.47 (72% agreement)				
Ortho Smile	Ortho Repose			
	Orthognathic	Prognathic	Retrognathic	Total
Orthognathic	11	1	0	12
Prognathic	0	1	0	1
Retrognathic	3	0	2	5
Total	14	2	2	18

Male κ=0.62 (80% agreement)			
Ortho Smile	Ortho Repose		
	Orthognathic	Retrognathic	Total
Orthognathic	4	0	4
Retrognathic	2	4	6
Total	6	4	10

Tables 7, 8 and 9. Oral surgeons judged repose and smiling profiles consistently 64% of the time. Judgements by oral surgeons agreed in 65% of female subjects and 75% of males.

κ=0.3304 (64% agreement)				
OS Smile	OS Repose			
	Orthognathic	Prognathic	Retrognathic	Total
Orthognathic	10	1	1	12
Prognathic	1	0	0	1
Retrognathic	6	0	6	12
Total	17	1	7	25

Female κ=0.29 (65% agreement)				
OS Smile	OS Repose			
	Orthognathic	Prognathic	Retrognathic	Total
Orthognathic	8	1	1	10
Prognathic	1	0	0	1
Retrognathic	3	0	3	6
Total	12	1	4	17

Male κ=0.33 (75% agreement)			
OS Smile	OS Repose		
	Orthognathic	Retrognathic	Total
Orthognathic	2	0	2
Retrognathic	3	3	6
Total	5	3	8

Table 10. Judgements by orthodontists agreed more with the majority than judgements by oral surgeons, but this was not statistically significant (p-value=0.6274).

	Repose (p-value=0.6274)		Smiling	
	No	Yes	No	Yes
Oral Surgeon	8 (26.67%)	22 (73.33%)	8 (26.67%)	22 (73.33%)
Orthodontist	3 (10.00%)	27 (90.00%)	5 (16.67%)	25 (83.33%)

Table 11. A clinically determined upper incisor to GV measurement was recorded by an experienced operator, then repeated by a second operator with 90% interrater reliability.

κ=0.95 (90% agreement)			
GV	Resident GV		
	0	1	Total
0	0	3	3
1	0	27	27

κ=0.95 (90% agreement)			
GV	**Resident GV**		
	0	**1**	**Total**
Total	0	30	30

Table 12. There was a statistically significant difference in diagnosis of the AP position of the maxilla using SNA, A-NPerp and GV. (p-value<0.0001)

Agreement of diagnoses from all 3 analyses?	Frequency	Percent
No	54	90.00
Yes	6	10.00

Table 13. Diagnoses using Steiner and McNamara agreed 50% of the time.

κ=0.09 (50% agreement)				
Steiner	**McNamara**			
	Orthognathic	**Prognathic**	**Retrognathic**	**Total**
Orthognathic	22	18	0	40
Prognathic	2	8	0	10
Retrognathic	10	0	0	10
Total	34	26	0	60

Table 14. Diagnoses using Steiner and GV agreed only 36% of the time.

	κ=0.04 (36% agreement)			
GV 1	**Steiner**			
	Orthognathic	**Prognathic**	**Retrognathic**	**Total**
Orthognathic	16	4	4	24
Prognathic	8	0	0	8
Retrognathic	16	6	6	28

	κ=0.04 (36% agreement)			
GV 1	**Steiner**			
	Orthognathic	**Prognathic**	**Retrognathic**	**Total**
Total	40	10	10	60

Table 15. Diagnoses using GV and McNamara agreed only 27% of the time.

κ=-0.12 (27% agreement)				
GV 1	**McNamara**			
	Orthognathic	**Prognathic**	**Retrognathic**	**Total**
Orthognathic	10	14	0	24
Prognathic	2	6	0	8
Retrognathic	22	6	0	28
Total	34	26	0	60

Tables 16 and 17. The same clinician repeated cephalometric tracings on 10 of the 30 radiographs more than one month after the initial tracings were completed. Intrarater reliability for the Steiner and GV analyses indicated high agreement.

IRR=0.7826			
Steiner	**Steiner 2**		
	Orthognathic	**Prognathic**	**Total**
Orthognathic	12	0	12
Prognathic	2	6	8
Retrognathic	0	0	0

IRR=0.8305				
GV 1	**GV 2**			
	Orthognathic	**Prognathic**	**Retrognathic**	**Total**
Orthognathic	8	0	0	8
Prognathic	0	2	0	2
Retrognathic	2	0	8	10
Total	10	2	8	20

Table 18. Intrarater reliability for the McNamara analysis was perfect.

IRR=1.00			
McNamara	**McNamara 2**		
	Orthognathic	**Prognathic**	**Total**
Orthognathic	8	0	8
Prognathic	0	12	12
Total	8	12	20

Table 19. A second operator repeated cephalometric tracings on 10 of the 30 radiographs. Interrater reliability for Steiner was 80%.

IRR=0.59 (80% agreement)			
Steiner	**Steiner 2**		
	Orthognathic	**Prognathic**	**Total**
Orthognathic	5	1	6
Prognathic	1	3	4
Retrognathic	0	0	0
Total	6	4	10

Tables 20 and 21. Interrater reliability for GV and McNamara analyses was perfect.

IRR=1.0 (100% agreement)				
GV	**GV CJ**			
	Orthognathic	**Prognathic**	**Retrognathic**	**Total**
Orthognathic	4	0	0	4
Prognathic	0	1	0	1
Retrognathic	0	0	5	5
Total	4	1	5	10

IRR=1.00 (100% agreement)			
McNamara	**McNamara CJ**		
	Orthognathic	**Prognathic**	**Total**
Orthognathic	2	2	4
Prognathic	3	3	6
Total	5	5	10

Table 22. Diagnosis with the Steiner analysis correlated best with judgement of repose profiles, whereas judgement of smiling profiles agreed most with diagnosis using the GV analysis.

	Repose		**κ**	**Smiling**		**κ**
	No	**Yes**		**No**	**Yes**	
GV	15 (52%)	14 (48%)	0.15	13 (46%)	15 (54%)	0.19
Steiner	12 (41%)	17 (59%)	0.19	16 (57%)	12 (43%)	-0.03
McNamara	18 (63%)	11 (37%)	-0.13 *disagreement	21 (75%)	7(25%)	-0.14 *disagreement

Table 23. Judgement of repose female profiles correlated best with diagnosis using the Steiner analysis, while diagnosis using GV correlated best with judgements of male repose profiles.

	Female Repose		**κ**	**Male Repose**		**κ**
	No	**Yes**		**No**	**Yes**	
GV	11 (58%)	8 (42%)	-0.04	4 (40%)	6 (60%)	0.38
Steiner	6 (32%)	13 (68%)	0.20	6 (60%)	4 (40%)	-0.09
McNamara	11 (58%)	8 (42%)	-0.18	6 (60%)	4 (40%)	-0.11

Table 24. Diagnosis using the Steiner analysis correlated best with judgements of female smiling profiles. Diagnosis using GV for cephalometric analysis correlated best with judgements of male smiling profiles.

	Female Smiling		κ	Male Smiling		κ
	No	**Yes**		**No**	**Yes**	
GV	9 (53%)	8 (47%)	0.19	4 (37%)	7 (63%)	0.27
Steiner	8 (47%)	9 (53%)	0.21	8 (72%)	3 (28%)	-0.17
McNamara	9 (47%)	10 (53%)	0.19	7 (64%)	4 (36%)	-0.29

Table 25. Cephalometric diagnosis with the Steiner analysis correlated best to judgements of repose profiles by orthodontists. Judgements of smiling profiles by orthodontists correlated best with analysis using GV.

Orthodontists	Repose		κ	Smiling		κ
	No	**Yes**		**No**	**Yes**	
GV	17 (59%)	12 (41%)	-0.08	13 (45%)	16 (55%)	0.22
Steiner	12 (41%)	17 (59%)	0.13	15 (48%)	14 (42%)	0.07
McNamara	17 (59%)	12 (41%)	-0.08	21 (72%)	8 (28%)	-0.13

Table 26. Cephalometric diagnosis using the Steiner analysis correlated best with judgements of repose profiles by oral surgeons. Cephalometric diagnosis using GV for analysis correlated best with judgements of smiling profiles by oral surgeons.

Oral Surgeons	Repose		κ	Smiling		κ
	No	**Yes**		**No**	**Yes**	
GV	13 (46%)	15 (54%)	0.19	10 (37%)	17 (63%)	0.33
Steiner	10 (36%)	18 (64%)	0.24	17 (63%)	10 (37%)	-0.05
McNamara	17 (72%)	11 (28%)	-0.12	19 (78%)	6 (22%)	-0.16

Discussion

All 3 null hypotheses were rejected. There was a difference in judged AP maxillary jaw position using repose and smiling profiles. There was a difference in cephalometric diagnosis of the AP position of the maxilla using GV, Steiner and McNamara analyses. There was a correlation between clinical judgement of repose and smiling profiles and cephalometrics using GV and Steiner analyses.

There was not complete agreement in judged AP maxillary jaw position using repose and smiling profile photographs. This discrepancy alone does not indicate whether either the repose or smiling profiles are superior for diagnosis but may suggest that inclusion of both repose and smiling profiles is necessary for comprehensive treatment planning. There was better agreement between judgement of repose and smiling profiles in males than in females. This may suggest that there is a lesser discrepancy between hard tissue anatomy and soft tissue esthetics in males, as compared to females. Orthodontists were more discerning than oral surgeons in clinical impression of the AP position of the maxilla, but this finding was not statistically significant.

Interrater reliability for the clinical measurement of GV, determined within a 1mm range, was excellent. This finding confirms the reproducibility of the measurement, and further supports its use as reliable extracranial referent.

There was a statistically significant difference in the diagnosis of the AP position of the maxilla using GV, Steiner and McNamara analyses. This confirms the findings of previous studies that described an inconsistency in diagnosis with cephalometric analyses. Diagnosis with the Steiner analysis showed some, albeit poor, agreement with diagnosis by both the GV and McNamara analyses. Diagnoses from the GV and McNamara analyses disagreed. These results, in isolation, cannot be used to determine which analysis is superior in its diagnosis of the AP position of the maxilla.

When the same operator repeated the cephalometric tracings and analyses, there was good agreement for the Steiner analysis, very good agreement for the GV analysis, and perfect agreement for the McNamara analysis. When a second operator traced the cephalometric radiographs, there was perfect agreement for the McNamara and GV analyses, but only fair agreement for the Steiner analyses. Steiner showed the least amount of intrarater and interrater reliability, which may confirm concerns about intracranial landmark identification. Interestingly, the McNamara analysis, which also utilizes an intracranial referent, demonstrated perfect intrarater and interrater reliability. GV, the only analysis in this study to use an extracranial referent, performed extremely well, with very good intrarater reliability and perfect interrater reliability. This supports the notion that extracranial referents are reliable but does not confirm that the extracranial referent outperformed the intracranial referent in this study.

Clinical judgement of the repose profiles correlated best with the Steiner analysis, closely followed by the GV analysis. Clinical judgement of the smiling profiles correlated best with the GV analysis. These findings were consistent when looking at clinical impressions by orthodontists and oral surgeons separately. In females, clinical judgement of the repose and smiling profiles correlated best with diagnosis by the Steiner analysis. In males, clinical judgement of the repose and smiling profiles correlated best with diagnosis using the GV analysis. There was no agreement between clinical judgement and diagnosis using the McNamara analysis, which suggests that it may not be a useful tool for comprehensive treatment planning. As was previously mentioned, there was better agreement between clinical judgement of smiling and repose profiles in males compared to females, so correlation of the male judgements and diagnosis with the GV analysis may suggest that the GV analysis has a more universal application in orthodontic treatment planning.

A correlation between clinical judgement and cephalometric diagnosis of the AP position of the maxilla was established using GV and Steiner analyses. This conclusion, paired with the fact that the Steiner analysis performed poorly in intrarater and interrater reliability for diagnosis of the AP position of the maxilla, may suggest that the GV analysis is the most valid cephalometric analysis examined in this study. The reliability of the GV analysis, paired with its correlation to clinical impression, suggests that it is a useful tool in the diagnosis of the sagittal position of the maxilla.

The study operated under the assumptions that the clinical judgements of GV were reliable, that a single operator accurately traced the cephalometric radiographs with reproducible measurements, and that the dental specialists who judged the clinical photographs had no prior knowledge of the study hypotheses.

The first 10 patients identified as having negative GV, neutral GV, and positive GV values were enrolled in the study, but it is questionable as to whether or not there was an equal distribution of prognathic, orthognathic, and retrognathic maxillae included in the study group. This study only investigated records of Caucasian patients, using Caucasian cephalometric norms, therefore, conclusions cannot be generalized to all populations. Similarly, maxillary prognathism in Caucasians is not prevalent, so true prognathism may be underrepresented in this study. Future research of other ethnicities will allow for a broader understanding of these diagnostic approaches. Only orthodontists and oral surgeons, who had specialized training in diagnosis of facial esthetics, were polled for clinical impressions of the AP position of the maxillae. Inclusion of other dental professionals or laypersons may yield different results.

There are established standard deviations that define the normal ranges for the Steiner and McNamara analyses, but there is no established range for the GV analysis. This study proposed a narrow standard deviation +/-1mm, but future studies on this analysis may elucidate a definite range of norm values. If the range was wider than +/-1mm, the study may have yielded more significant results.

The Steiner, McNamara and GV analyses all utilize 2-dimensional cephalometric radiographs. Future research using a 3-dimensional analysis may be superior to all three analyses investigated in this study.

Conclusion

1. Because there is a difference in clinical judgement of repose and smiling profiles, both should be included in diagnostic records for comprehensive orthodontic treatment planning.
2. The Steiner and GV analyses are useful tools for diagnosing the AP position of the maxilla on a cephalometric radiograph.
3. The GV analysis may be a more valid analysis due to its use of an extracranial referent and its superior correlation to clinical impressions of smiling profiles.

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