Original Article

Are all mandibles golden? A cephalometric study of mandibular morphology as compared to the golden proportion

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Abstract

Objective: To evaluate the ratio of the condylar axis and corpus axis of the mandible in subjects with different growth pattern and sagittal skeletal relation. To assess if the above ratio is similar to the golden ratio in all the groups of patients. **Materials and Methods:** pretreatment lateral cephalograms of adult patients were analyzed and six groups were selected with 30 patients in each group. (male: 15, female: 15). The characteristics of each group were: Group 1 — patients with average growth pattern, Group 2 — horizontal growth pattern, Group 3 — vertical growth pattern, Group 4 — class-I skeletal bases, Group 5 — class-II skeletal bases, and Group 6 — class-III skeletal bases. The cephalograms were traced manually and the ratio between condylar and corpus axis was calculated using Golden ratio software (http://www.markuswelz.de/software2/index.html). The mean ratio for each group was calculated and this ratio was compared with the golden ratio (0.6180) using sample t test. P value was set at 0.05. **Results:** No statistically significant difference ($P > 0.05$) was found between the mean value of the ratio of condylar to corpus axis of the mandibles and the golden ratio in all groups except the vertical growth pattern group ($P < 0.01$). **Conclusion:** In the sample studied, the ratio of condylar axis to corpus axis in all groups closely matches the golden ratio except in the vertical growth pattern patients where the ratio was significantly reduced (0.6151).

Key words: Condylar axis, corpus axis, golden ratio, mandible

INTRODUCTION

The normal human face was considered by Ricketts to be the most beautifully perfect structure in all of the animal kingdom.[1] In an attempt to study the face, Ricketts[1] explored the "divine proportion" in relation to the dentofacial complex, claiming that a number of golden relationships existed in the faces, cephalograms, and study casts of those considered to have outstanding beauty. The divine proportion, also commonly referred to as the golden proportion, the golden section, or phi, is defined as the point where a line is sectioned so that the ratio of the small to the large section is the same as that of the large section to the whole line. The larger section is 1.618 times that of the shorter one.[2] Figure 1 shows a line divided according to the divine proportions. The ratio of the smaller segment to the larger segment is 0.6180 and the ratio of the larger segment to the smaller is 1.618. Ghyka pointed out the repeated occurrence of the divine proportion in natural forms such as flowers, shells, and also, the human body.[2]

Among the facial structures perhaps no other bone has commanded more attention from the scientific literature than the mandible. The form and size of the mandible has been studied extensively and whether or not it can be

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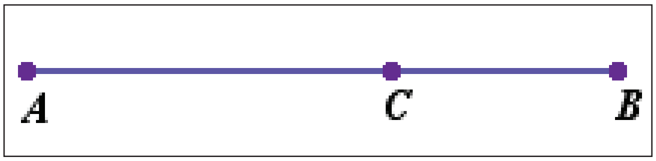

Figure 1: The line AB is divided by point C in such a way that the ratio of AC to CB is equal to the ratio of AB to AC. The ratio of AC to CB is equal to 1.618 and the ratio of CB to AC is 0.618

modified by growth modulation has been debated with the same vigor. Ricketts[1] in 1979 studied a sample of 30 ideal, normal, racially unmixed adult males from Peru, South America. Their lateral cephalograms were traced and digitized. The result was a composite of what could be considered to be the ideal face and in that composite eight divine proportions were discovered. In every normal composite of mandibles studied, the corpus axis was in divine proportion to the condyle axis when measured to the top of the condyle. This approach makes an excellent tool to determine mandibular dysplasia because the relationship is valid irrespective of age.[1]

In a study by Pancherz[3] to answer the question, "to what extent do facial proportions change in comparison with the divine values during growth?" the changes of the facial proportions in ordinary subjects were analyzed with full-face photos from 20 female and 20 male subjects. The facial photos from childhood, adolescence, and adulthood of each subject were compared. The facial proportions changed, on average, only a small amount during the growth period from childhood to adulthood, but large variations were seen. In comparison with the divine values, facial proportions in both sexes remain rather constant during growth.[3]

The mandible, which was studied using the Xi point by Ricketts,[4] is perhaps one of the most variable structures in morphology and size. It differs in form patient to patient and plays a crucial role in facial balance and beauty. The purpose of this study was to analyze and group patients based on the growth pattern and sagittal skeletal dysplasia and to evaluate the ratio of the condylar axis and corpus axis of the mandible in patients among the different groups. The second aim was to assess if this ratio matches the golden ratio in all the groups of patients.

MATERIALS AND METHODS

Lateral cephalograms of untreated subjects were used for this study from the records of the author's private practice and the records of the Department of Orthodontics and Dentofacial Orthopedics, Vydehi Institute of Dental Sciences, Bangalore, India. The inclusion criteria were:

- No history of orthodontic or surgical treatment
- Adult non growing individuals
- Mild to moderate malocclusion or skeletal dysplasia
- No syndrome or any medical condition involving head and neck region

The exclusion criteria were

- History of previous orthodontic treatment
- Severe skeletal dysplasia such as syndromes, craniofacial deformities
- Growing individuals

The pretreatment lateral cephalograms of the patients were traced manually and analyzed. The landmarks were located and the following parameters were recorded:

- ANB angle to indicate the sagittal skeletal relation
- Mandibular plane (MP) to SN plane angle to indicate the growth pattern
- Condylar axis — from Xi point to DC point in the condyle and extended to the top of condyle.[4] Xi point is the centre of the ramus as described by Ricketts.[4]
- Corpus axis — from Xi point to Suprapogonion (Pm)[4]
- Mandibular arc — posterior angle formed between condylar axis and extension of corpus axis.[4]
- Linear distance between occlusal plane (OP) and Xi point. Ricketts postulated that the occlusal plane had a strong tendency to pass through the Xi point.[4]
- Ratio of condylar axis to Corpus axis, when condylar axis was measured from the top of condyle.

All the tracings of the cephalograms were scanned and digitized. The length of the condylar axis, corpus axis, and the ratio between condylar and corpus axis was calculated using Golden ratio software (available online for download (http://www.markuswelz.de/software2/index.html)) on the digital image of the tracing. Figure 2 shows the ratio being calculated using the software from the scanned tracing of the patient. Using this software, the operator only has to draw the lines corresponding to the condylar and corpus axis using the mouse on the scanned image of the tracing and the software calculates the length of condylar axis, corpus axis, and the ratio between the two up to the fourth decimal point.

The patients were categorized into six groups of 30 cases each with 15 males and 15 females. The characteristics of each group were

1. Group 1 — patients with average growth pattern. Selection criteria were mandibular plane angle (MP-SN) in range of 30° to 34° and mandibular arc in range of 22° to 30°.
2. Group 2 — patients with the horizontal growth pattern. Selection criteria were mandibular plane angle

(MP- SN) less than 30° and mandibular arc greater than 30°.
3. Group 3 — patients with the vertical growth pattern. Selection criteria were the mandibular plane angle (MP- SN) greater than 34° and mandibular arc less than 22°.
4. Group 4 — patients with class-I skeletal bases. Selection criteria were ANB value in range of 1° to 3°.
5. Group 5 — patients with class-II skeletal bases. Selection criteria were ANB value greater than 3°.
6. Group 6 — patients with class-III skeletal bases. Selection criteria were ANB value less than 1°.

The mean values and standard deviation of age, ANB value, mandibular plane angle (MP-SN), mandibular arc, condylar axis, corpus axis, ratio of condylar to corpus axis, and the distance from occlusal plane to Xi point (OP-Xi) for the 30 sample size was calculated for each group separately.

The mean of the ratio of condylar to corpus axis that was calculated for each group was compared with the golden ratio (0.6180) using one sample t test. The null hypothesis was that the computed mean value was not significantly different from the given ideal value. The alternate hypothesis was that the computed mean value is significantly different from the given ideal value. The level of significance was set as $P = 0.05$.

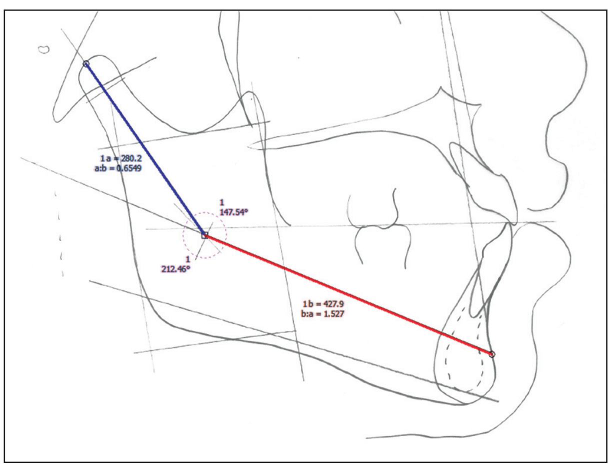

Figure 2: Tracing of a patient with the golden ratio software being used

RESULTS

Figure 3 shows the comparison among the ratios in the different groups to the golden value of 0.618. Table 1 shows the statistical values of the ratio for each group.

In Group 1 (average growth pattern), the mean mandibular plane angle was 32° with a standard deviation or SD of 1.55 and the mean mandibular arc value was 26.5° with SD of 2.36. In this group the mean of the ratio of the condylar to corpus axis was 0.6177 with SD of 0.0162. This value was not significantly different from the golden value of 0.6180.

In Group 2 (horizontal growth pattern), the mean mandibular plane angle was 26.13° with SD of 2.81 and the mean mandibular arc value was 34.5° with SD of 2.06. In this group, the mean of the ratio of the condylar to corpus axis was 0.6191 with SD of 0.0108. This value was not significantly different from the golden value of 0.6180.

In Group 3 (vertical growth pattern), the mean mandibular plane angle was 37.4° with SD of 2.14 and the mean mandibular arc value was 19.43° with SD of 1.3. In this group, the mean of the ratio of the condylar to corpus axis

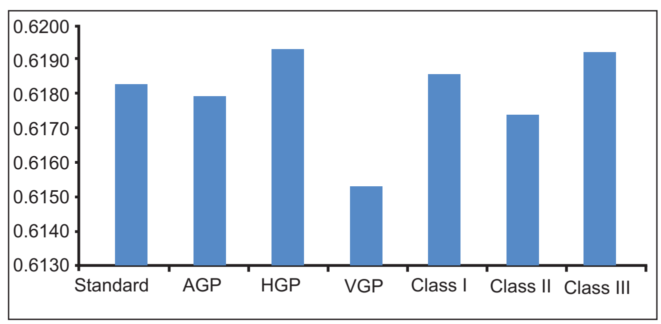

Figure 3: Graph comparing the ratio of the condylar axis to corpus axis among the various groups

Table 1: Mean and standard deviation (std dev) of the ratio of the condylar to corpus axis in the different groups

Group	Mean ratio	Std dev	SE of mean	Min	Max	t	*P*-value
AGP	0.6177	0.0162	0.0030	0.5998	0.6704	–0.140	0.893
HGP	0.6191	0.0108	0.0020	0.6044	0.6654	0.560	0.581
VGP	0.6151	0.0049	0.0009	0.6014	0.6220	–3.240	0.003*
Class I	0.6183	0.0159	0.0029	0.6001	0.6704	0.100	0.918
Class II	0.6172	0.0159	0.0029	0.5998	0.6704	–0.280	0.785
Class III	0.6190	0.0155	0.0028	0.6014	0.6704	0.350	0.726

AGP – average growth pattern; HGP – horizontal growth pattern; VGP – vertical growth pattern, class-I sagittal relation, class-II sagittal relation, and class-III sagittal relation was 0.6151 with SD of 0.0049. The *P* value was found to be 0.003 which was significantly different from the golden value of 0.6180.

In Group 4 (class I sagittal relation), the mean ANB angle was 2.1° with SD of 0.96. In this group, the mean of the ratio of the condylar to corpus axis was 0.6183 with SD of 0.0159. This value was not significantly different from the golden value of 0.6180.

In Group 5 (class II sagittal relation), the mean ANB angle was 6.8° with SD of 1.53. In this group, the mean of the ratio of the condylar to corpus axis was 0.6172 with SD of 0.0159. This value was not significantly different from the golden value of 0.6180.

In Group 6 (class III sagittal relation), the mean ANB angle was –1.57° with SD of 1.14. In this group, the mean of the ratio of the condylar to corpus axis was 0.6190 with SD of 0.0155. This value was not significantly different from the golden value of 0.6180.

Another parameter studied by us was the linear distance between occlusal plane (OP) and Xi point. Ricketts postulated that the occlusal plane had a strong tendency to pass through the Xi point.[4] In this study, in all the groups the mean of the distance from the occlusal plane to the Xi point was similar. Table 2 shows the mean values and SD of this distance in all groups. The occlusal plane was found to pass superior to the Xi point contrary to the statement by Ricketts. This could possibly be due to the occlusal plane being very variable and influenced by many local factors such as supraeruption of teeth, etc.

DISCUSSION

In this study, we have attempted to study mandibular morphology among different groups of patients and have tried to find if any common factor can be deduced in all groups.

Table 2: Mean and standard deviation of the distance of the occlusal plane to Xi point in the various groups

Group	Mean of OP to Xi (mm)	Std dev (mm)
AGP	1.28	2.18
HGP	1.15	2.10
VGP	1.27	2.12
Class I	1.32	2.05
Class II	1.68	2.48
Class III	1.12	2.30

AGP – average growth pattern; HGP – horizontal growth pattern; VGP – vertical growth pattern, class-I sagittal relation, class-II sagittal relation, and class-III sagittal relation

The reason the ratio between the condylar axis and the corpus axis was chosen to describe the mandibular morphology is simple. An important limitation of lateral cephalometric analyses is that any difference in size amongst patients reduces the value of absolute measurements in defining whether or not a particular patient has normal or ideal facial relationships. The use of the divine proportion[1] has been proposed to overcome some of these problems, because it is based on proportional rather than absolute measures.

In group 1 (average growth pattern) patients, the ratio matched the golden proportion as these cases were all patients with normal form who did not have any skeletal discrepancies. This supported the findings of the earlier study by Ricketts.[1] In Group 2 (horizontal growth pattern) patients, the ratio again matched the golden ratio. One explanation for this could be that in these cases although the mandible had a forward rotation tendency, the corpus and the ramus were in still in harmony to each other. For example if a patient had a long ramus then even the corpus was correspondingly long. Hence, the proportion between the corpus and ramus was maintained.

In Group 3 (vertical growth pattern) patients, the mean ratio was reduced compared to the golden ratio and the difference was significant. This finding could be attributed to the fact that in severe vertical growing mandibles the ramus length could have been shortened and this could have reduced the ratio.

In Group 4 (class-I sagittal relation) patients, the ratio matched the golden proportion. In this study, in Group 5 (class II sagittal relation) patients also the ratio matched the golden proportion. The reason for the same could be that in cases with prognathic maxilla and retrognathic mandible, although there was a mismatch between the maxilla and mandible, the mandible was probably small in both ramus height and corpus length leading to no variation in the ratio. This was in contrast to the findings of Shell and Woods.[5] They designed a study to compare selected divine or golden proportions in class-II division 1 patients were treated either during the growth phase with an activator and fixed appliances or after the completion of growth with fixed appliances and orthognathic surgery and to determine the associations between divine facial proportions and perceived facial attractiveness. They studied various parameters on lateral cephalograms and photographs. On average, few ratios fitted the divine proportion, either before or after treatment in either treatment group. Regardless of the treatment method, ratios in some patients moved toward the divine proportion, while those in others moved away from it. They concluded that neither treatment method was more likely to result in a greater number of divine proportions, nor the achievement of divine proportions seemed to have little, if any, influence on overall aesthetic outcomes.[5]

In Group 6 (class III sagittal relation) patients, the ratio matched the golden proportion. Here similar reasoning as in Group 5 could be applied to explain the findings.

This study uses modern software to reconfirm the findings of Ricketts that the human face and the mandible in particular follow the divine or golden proportion. In this study, the sample selection criteria eliminated patients with severe skeletal dysplasia such as syndromes where it could have been more likely to find deviation from the golden proportion. This study helps us analyze the mandible and could be useful as a clinical tool to study the relation between ramus and corpus and compare it to the golden ratio.

In the future, a study could be conducted on different racial populations and on a larger sample size to evaluate the validity of the divine proportion.

CONCLUSION

To summarize, this study was conducted to evaluate the validity of the golden proportion in mandibles of patients with different growth patterns and different sagittal base relationships using golden proportion software. In the sample studied, the ratio of condylar axis to corpus axis in all groups matched the golden ratio except in the vertical growth pattern patients where the ratio was significantly reduced (0.6151).

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