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The role of the divine proportion in the esthetic improvement of patients undergoing combined orthodontic/orthognathic surgical treatment

This study was designed to investigate the changes in a number of facial proportions as a result of combined orthodontic/orthognathic surgical treatment. According to some authors, in beautiful faces, the values of the proportions measured are likely to approximate the divine proportion (1.618:1). The hypothesis for this study was that, as a result of treatment, the faces of patients in the sample would be more esthetic and therefore the measured proportions would be closer to the divine proportion than they were before treatment. Forty-six patients were included in the sample. Pre- and posttreatment photographs were each given a score (out of a possible 100) by 12 judges using a visual analog scale. Judges were shown frontal and profile views simultaneously. Ten ratios were measured from pre- and posttreatment lateral cephalograms, and 11 were measured from the frontal photos. Pearson's correlation coefficient was used to determine the correlation between changes in esthetic rating and changes in the measured proportions. No correlations were found between changes in esthetic ratings and changes in the proportions. While most subjects were considered more esthetic after treatment than before, the proportions were equally likely to move away from or toward the divine proportion. For this reason, if it is to be used as an aid to orthodontic/orthognathic treatment planning, the divine proportion should perhaps be used along with other methods of anteroposterior and vertical cephalometric and facial assessment. (Int J Adult Orthod Orthognath Surg 2001;16:108–120)

The "divine proportion" is one of several terms used to describe the division of a line such that the ratio of the smaller section to the larger section is the same as that of the larger section to the whole.[1] Other names given to this ratio include "the division of a line into extreme and mean ratio," the "golden proportion," and the "golden section."[2] This ratio can be expressed mathematically as 1.618:1 or 1:0.618. This division of a line can be traced to a number of theorems in Euclid's *Elements,* although others have suggested that it was used prior to this, even being used in the construction of the Great Pyramid of Cheops.[3] It has also been associated with the Fibonacci sequence of numbers, in which the division of one number in the sequence by the preceding number yields the divine proportion.[4]

There have been many claims that the divine proportion was used in Greek art and architecture by the sculptor Phidias. This has led to its nickname as the "Phi" ratio.[5] The term "divine proportion" was first used by the Italian Renaissance mathematician Fra Luca Pacioli.[6,7] While some authors have claimed that the divine proportion was used definitively by Renaissance artists to proportion their works,[8,9] many of these theories are retrospective and unsupported by evidence.[10,11]

A movement supporting the divine proportion began in Germany in the mid-19th century, when the term "golden section" was first used.[2] It was Zeising who first suggested that the golden section had particular esthetic qualities and that anything composed in this proportion would be considered beautiful.[10] At the time, this theory was supported by the esthetic experiments of Fechner,[12] who showed that people preferred rectangles whose sides were in the divine proportion versus other rectangles.

From this time on, debate has raged as to the esthetic qualities of the divine proportion, and many have questioned the validity of Fechner's findings.[13–15] The use of the proportion in art and architecture has, again, been both advocated and condemned.[16–19] It may have been used in the Cubism movement in art,[20] but again the evidence for this is contradictory.[21] Perhaps the most acclaimed proponent of the golden section in recent times was the French architect Le Corbusier, who based his Modulor system on this ratio.[22] The divine proportion has also been claimed to have been used in music,[23,24] has been identified in the growth and structure of plants (phyllotaxis),[25–27] and may even play a role in psychology and personal relationships.[28]

In 1946 Matila Ghyka, in his text *The Geometry of Art and Life,*[29] presented an analysis of the face of tennis champion Helen Wills, in which several measurements are shown to be in the divine proportion. Based partly on Ghyka's analysis, Seghers et al[30] described the reconstruction of a facial deformity using the divine proportion as a planning tool. Levin[31] and others[32,33] have suggested that the divine proportion also provides a guide for the ideal sizes of teeth and could be used to aid prosthodontic treatment. Again, others have disagreed.[34] In 1982, Ricketts[35] claimed to have found a large number of golden proportions after examining lateral and frontal cephalograms that he considered ideal. He also found, after examining photos of models, a number of divine ratios within the face. Ricketts[35,36] therefore advocated the use of these divine proportion ratios as guides for planning orthognathic surgery. With all this in mind, the present study was designed to test the hypothesis that esthetic improvement after combined orthodontic/orthognathic surgical treatment could be correlated with a movement of these ratios toward the divine proportion.

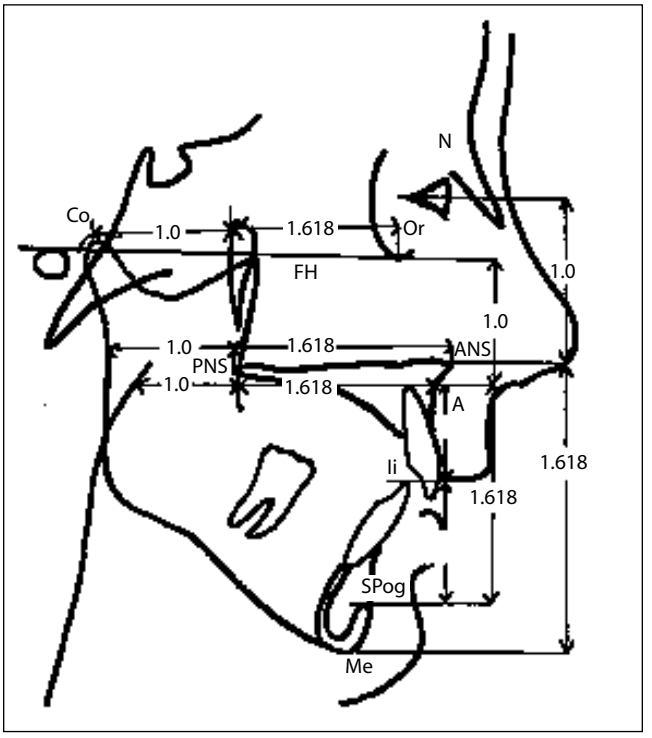
Materials and methods

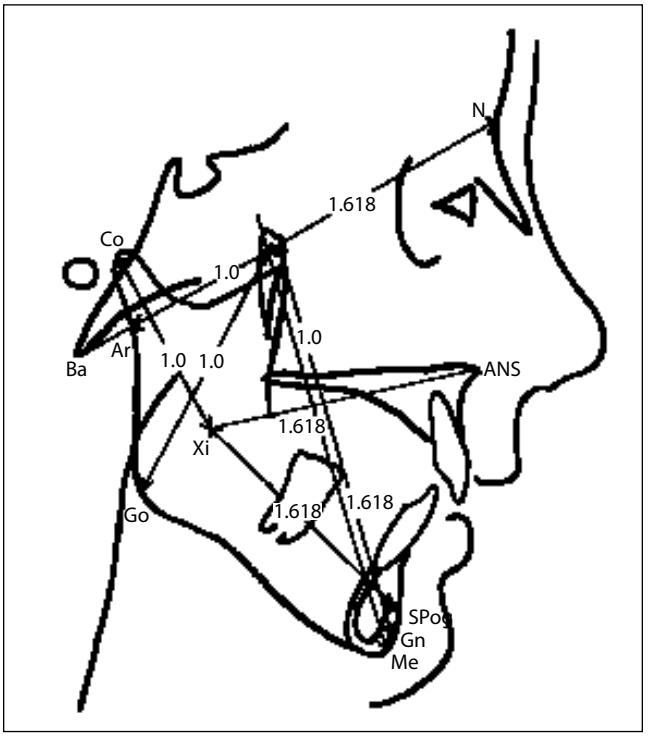
The sample consisted of 46 patients and was taken from the records of 2 specialist orthodontists in private practice and from the records of the University of Melbourne Orthodontic Graduate Clinic. The only criteria for selection were that the patients had undergone a combined orthodontic/orthognathic surgical treatment and that pre- and posttreatment lateral cephalographs and pre- and posttreatment frontal (non-smiling) and profile color facial photos were available. The sample consisted of 36 women and 10 men ranging in age from 15.1 to 46.3 years (mean, 24.5 years; standard deviation 8.4 years). Twenty-three of the patients had undergone bimaxillary surgery, 4 received maxillary surgery only, and 19 had mandibular surgery only.

Measurements

The pre- and posttreatment lateral cephalographs were hand-traced, and 10 of the 13 ratios that Ricketts[35,36] had suggested should be in the divine proportion were measured. These were:

1. Corpus axis length (1.618):condylar axis length (1.0)
2. Basal or cranial anterior base length (CC to N):distance from CC to Ar
3. Length of the hard palate (ANS-PNS):distance from PNS to the posterior border of the mandible
4. Distance from A to the anterior border of the mandible:distance from the anterior border of the mandible to the outline of the pharynx
5. Anterior length of FH (PtV to Or):distance from PtV to the glenoid fossa
6. Facial axis length (CC to Gn):posterior facial height (CC to Go)
7. Lower facial axis (Gn to ANS-Xi line): upper facial axis (the ANS-Xi line to CC)





Figs 1a and 1b Divine proportion measurements from lateral cephalograms as per Ricketts.[35,36]

8. Distance from SPog to A:distance from A to FH
9. Distance from Me to the palate at the incisive canal:distance from the palate at the incisive canal to Ex
10. Distance from SPog to Ii:distance from Ii to A

These ratios are illustrated in Figs 1a and 1b. Three ratios that Ricketts[35,36] suggested were in the divine proportion were not measured. Two of these were the ratios S-N:S-Ba and the ratio ramus height (R3 to R4):ramus depth (R1 to R2). It was felt that orthognathic surgery would not alter these ratios. The third was the ratio PtV to the mesial of the mandibular first molar:mesial of the manidibular first molar to incision inferius. Ricketts[36] claimed to have used "normal" cases from a variety of sources to determine the proportions. It was not definitely stated, but it seems likely that these patients would not have had premolar extractions. The Peruvian patients that Ricketts originally examined,[35] for instance, all had 32 teeth. In the present sample, some patients had had teeth extracted as part of their treatment, and this would have greatly affected the measurement from the lower molar to the lower incisor.

The frontal photos were then analyzed to measure the following ratios, as suggested by Ricketts[35,36]:

11. Ex to Me (1.618):Tr (defined by Ricketts as "a point at a triangle where the aponeurosis of the skull starts") to Ex (1.0)
12. Tr to AL:AL to Me
13. Me to AL:AL to Ex
14. Ex to Ch:Ch to Me
15. Ex to AL:AL to Ch
16. Me to Ch:Ch to AL

These ratios are illustrated in Fig 2.

The following ratios were also calculated from the frontal photos, according to the analysis of Ghyka[29]:

17. Top of the head to Me (ie, head height) (1.618): maximum width of the head (1.0)

Landmarks used

A = point A
AL = alare lateralis (most lateral point of the ala of the nose)
ANS = anterior nasal spine
Ar = articulare
Ba = basion
CC = cranial center
Ch = cheilion
Co = condylion
Ex = exocanthion (lateral canthus of the eye)
FH = Frankfort horizontal
Gn = gnathion
Go = gonion
Ii = incision inferius
Me = menton
N = nasion
Or = orbitale
Pm = pterygomaxillare
PNS = posterior nasal space
PtV = pterygoid vertical
S = sella
SPog = suprapogonion, anteroinferior limit of mandibular dentoalveolus
Tr = trichion
Xi = calculated geometric center of the ramus

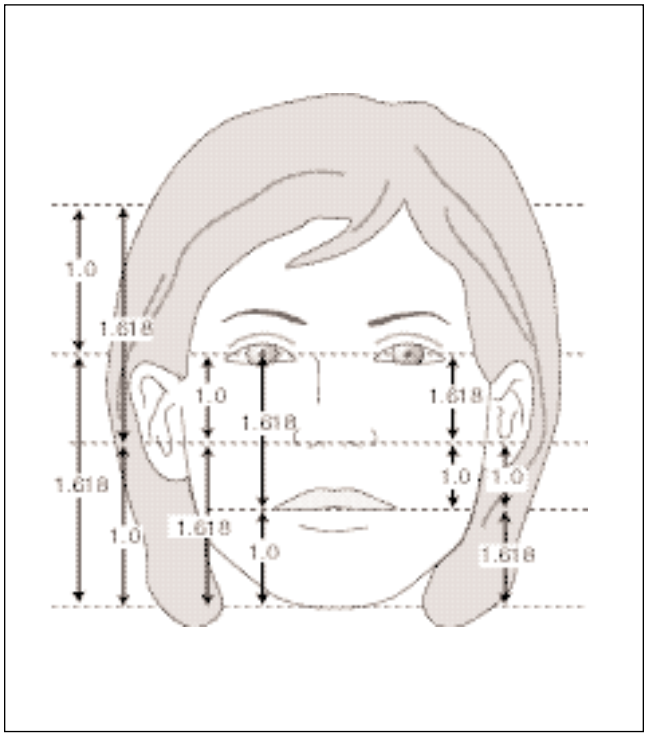


Fig 2 Divine proportion measurements from frontal photographs as per Ricketts.[35,36]

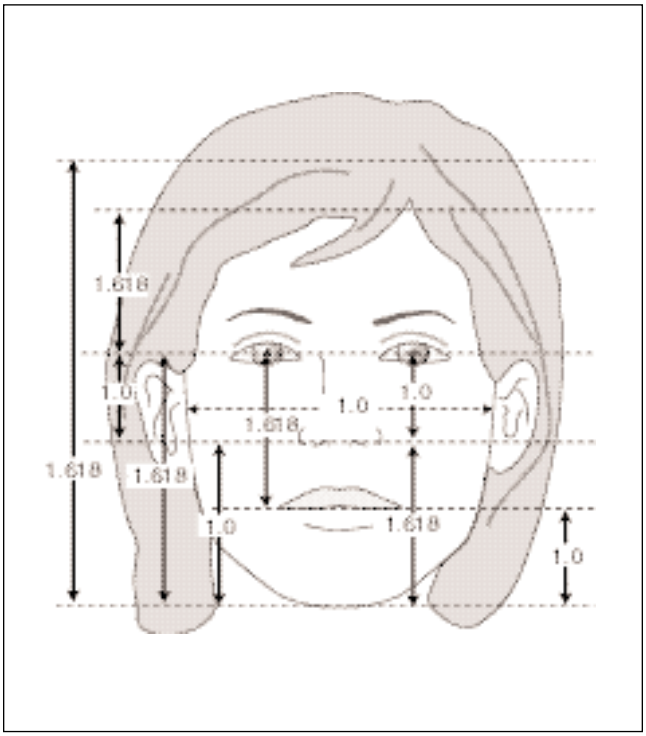


Fig 3 Divine proportion measurements from frontal photographs as per Ghyka.[29]

18. Ex to Me:AL to Me
19. Tr to Ex:Ex to AL
20. Ex to Ch:Ex to AL
21. AL to Me:Ch to Me

These ratios are illustrated in Fig 3. A sixth ratio suggested by Ghyka,[29] ie, the top of head to Ex:Tr to Ex, was not calculated as, again, it was felt that this ratio would not change with surgery.

Having measured these ratios for both pre- and posttreatment records, the authors then calculated the absolute difference (ie, the difference, regardless of whether it was positive or negative) of each ratio from the divine proportion. It was then possible to determine whether or not the ratios were closer to the divine proportion after surgery than they were before surgery and by how much. An error study was conducted 4 weeks after the initial measurements were made. Ten patients were chosen at random, and both pre- and posttreatment radiographs were retraced and the 20 cephalometric measurements redone. The 12 measurements that make up the 6 ratios determined from the frontal photos (as per Ricketts[35,36]) were also redone for each of these 10 patients. According to the Student *t* test, the level of measurement error was found to be insignificant.

Esthetic rating

Pre- and posttreatment frontal (nonsmiling) and profile photos were used for each patient. It was decided not to use a smiling photograph, since the irregularity of teeth might influence the esthetic rating of the patient. The photographs were of standard size, ie, 8×12 cm. The frontal and profile photos were placed next to each other in a photo album that accommodated 2 photos per page. Therefore, at any time, the frontal and lateral photographs of 2 patients were visible to the rater. The 92 sets of photographs were placed randomly within the album. An additional pair of photos of a patient not included in the sample was placed on the first page of the album to allow the judges to familiarize themselves with the procedure.

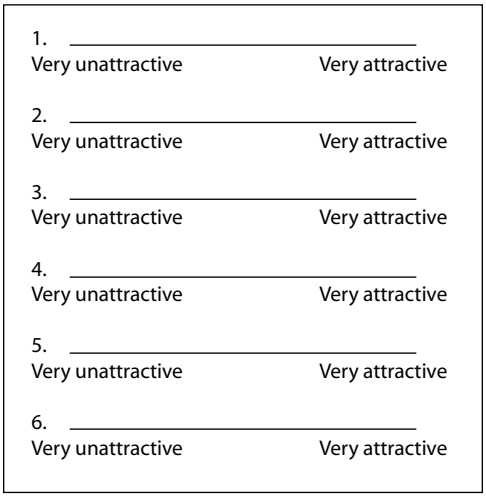


Fig 4 Example of scoring sheet used by judges when assessing attractiveness.

Twelve judges were chosen to rate the photographs: 2 orthodontists, 2 oral surgeons, 2 general dentists, 2 artists, 2 laypeople, and 2 people involved in the modeling industry. Six judges were male and 6 were female. Each judge was alone when the ratings were done. There was no time limit placed on the judges, but the total time averaged about 20 minutes. A 100-mm visual analog scale was used to record the judges' esthetic score for each set of photos (Fig 4). The analog scale was anchored at the left end with the words "very unattractive" and at the right end with the words "very attractive." Judges were instructed to view the frontal and profile photographs together and to record an overall rating by marking the scale where, between the 2 extremes, their rating of the patient's appearance would fit. The actual score was obtained by measuring the distance from the left end of the scale to the mark. This was similar to the method used by Phillips and coworkers in a number of studies.[37–39] The final esthetic rating for each patient, both pre- and posttreatment, was taken as the average score given by the 12 judges.

Each patient's change in the esthetic rating was determined in 2 ways: the percentage change and the actual numeric change. Pearson's correlation coefficients were obtained to determine the degree of correlation between the esthetic rating for each patient before and after surgery and the difference from phi for each ratio. Correlation coefficients were then determined to assess the degree of correlation between the change in esthetic rating and the change in the difference from phi for each ratio. This was based on the hypothesis that the ratios, as described by Ricketts[35,36] and Ghyka,[29] should be closer to the divine proportion in those cases in which surgery had resulted in improved facial appearance and that the greater the improvement, the greater should be the movement toward phi.

To assess intrarater reliability, the judges rated the entire sample again approximately 4 weeks after the first rating. This second rating was used only to assess reliability and was not included in the correlation study. Eleven of the 12 judges were available for this rerating. Analysis of variance was used to estimate the components of variance, and little difference was found between the first and second ratings.

Results

Tables 1 and 2 show the number of measured ratios that moved toward the divine proportion, moved away from the divine proportion, or remained unchanged. These results show no clear pattern of movement toward the divine proportion as a result of treatment.

Table 3 shows the average esthetic ratings of the patients before and after treatment and the rank order of the patients, from most esthetic improvement to least esthetic improvement. This is shown in 2 different forms, first in terms of percentage change and second in terms of the numeric change. It can be seen that the rankings of the patients in order of improved appearance differed little whether the percentage change or the numeric change was used.

Table 4 shows the correlation coefficients for the esthetic rating and the difference from phi for each of the measured ratios from the pre- and posttreatment lateral cephalograms. There appears to be no correlation between the two, either before or after treatment. Consistent with the hypothesis, one would have expected to

Table 1 Changes in measured ratios as measured from the lateral cephalograms

Ratio	No. moved toward phi	No. moved away from phi	No. unchanged
Pm to Xi:Xi to Co	25	20	1
N to CC:CC to Ar	16	20	10
ANS to PNS:PNS to posterior border of mandible	20	26	0
A to anterior border of mandible:anterior border of mandible to pharynx	21	24	1
Or to Ptv:Ptv to glenoid fossa	20	22	4
CC to Gn:CC to Go	22	24	0
Gn to ANS-Xi line:ANS-Xi line to CC	21	23	2
Pm to A:A to FH	24	21	1
Me to incisive canal:incisive canal to Ex	25	21	0
Pm to Ii:Ii to A	23	20	3

Table 2 Changes in measured ratios as measured from the frontal photos

Ratio	No. moved toward phi	No. moved away from phi	No. unchanged
Ex to Me:Tr to Ex	20	25	1
Tr to AL:AL to Me	17	28	1
Me to AL:AL to Ex	13	31	2
Ex to Ch:Ch to Me	21	23	2
Ex To AL:AL to Ch	11	31	4
Me to Ch:Ch to AL	24	19	3
Head height:head width	23	23	0
Ex to Me:AL to Me	19	24	3
Tr to Ex:Ex to AL	19	22	5
Ex to Ch:Ex to AL	15	24	5
AL to Me:Ch to Me	20	22	4

have seen a correlation between the esthetic rating and the difference from phi, so that those patients who were rated least attractive would have had ratios further from phi than those patients who were rated more attractive.

Similarly, Table 5 shows no correlation between the esthetic rating and the difference from phi for each of the ratios measured from the frontal photos.

Tables 6 and 7 show correlation coefficients relating the percentage and the numeric changes in esthetic ratings to the change in the difference from phi. No correlation was evident between the change in esthetic rating and the movement of each of the ratios toward or away from phi.

Discussion

The results of this investigation would seem to show that no relationship exists between changes in appearance as a result of orthodontic/orthognathic surgical treatment and changes in the values of those ratios that Ricketts[35,36] and Ghyka[29] claimed

Table 3 Average esthetic rating of patients before and after surgery and ranking of improvement by both percentage change and numeric change

	Esthetic rating		Ranking	
Patient no.	Presurgery	Postsurgery	Percentage change	Numeric change
1	14.0	47.7	1	1
2	23.3	48.5	2	2
3	25.2	44.6	3	3
4	25.2	42.6	4	5
5	26.1	42.9	5	7
6	27.1	44.4	6	6
7	25.5	41.8	7	8
8	15.6	25.5	8	13
9	31.6	50.0	9	4
10	30.3	43.3	10	11
11	22.8	32.4	11	15
12	37.4	52.1	12	9
13	35.6	47.8	13	11
14	28.7	38.3	14	16
15	41.5	54.9	15	10
16	27.0	35.7	16	19
17	29.5	38.3	17	18
18	21.0	26.7	18	24
19	37.1	47.0	19	14
20	42.5	52.2	20	17
21	39.0	46.8	21	21
22	34.3	40.9	22	22
23	47.0	55.3	23	20
24	35.7	41.7	24	23
25	32.2	36.9	25	26
26	36.0	40.3	26	27
27	33.4	37.1	27	29
28	26.3	29.1	28	33
29	44.8	49.6	29	25
30	36.3	39.8	30	30
31	43.4	47.5	31	28
32	36.0	39.0	32	32
33	38.5	41.0	33	34
34	53.7	57.1	34	31
35	31.1	32.3	35	36
36	43.8	45.3	36	35
37	39.3	38.9	37	37
38	21.6	21.1	38	38
39	39.8	38.2	39	39
40	39.9	38.2	40	41
41	35.4	33.8	41	40
42	53.8	50.4	42	44
43	43.3	40.3	43	42
44	50.1	45.9	44	45
45	36.8	33.5	45	43
46	41.6	33.9	46	46

Table 4 Correlation between difference from phi and average esthetic ratings for ratios determined from lateral cephalograms

		Correlation coefficient	
Ratio	n	Pretreatment	Posttreatment
Pm to Xi:Xi to Co	46	–0.425*	–0.149
N to CC:CC to Ar	46	0.226	–0.157
ANS to PNS:PNS to posterior border of mandible	46	–0.236	–0.024
A to anterior border of mandible:anterior border of mandible to pharynx	46	–0.096	–0.112
Or to Ptv:Ptv to glenoid fossa	46	0.195	–0.090
CC to Gn:CC to Go	46	–0.151	–0.007
Gn to ANS-Xi line: ANS-Xi line to CC	46	–0.002	–0.090
Pm to A:A to FH	46	0.102	–0.135
Me to incisive canal:incisive canal to Ex	46	–0.070	0.078
Pm to Ii:Ii to A	46	0.025	–0.114

*$P < .01$.

Table 5 Correlation between difference from phi and average esthetic ratings for ratios determined from frontal photos

		Correlation coefficient	
Ratio	n	Pretreatment	Posttreatment
Ex to Me:Tr to Ex	46	–0.109	0.186
Tr to AL:AL to Me	46	0.050	–0.082
Me to AL:AL to Ex	46	0.123	–0.180
Ex to Ch:Ch to Me	46	0.002	–0.041
Ex to AL:AL to Ch	46	0.079	–0.170
Me to Ch:Ch to AL	46	–0.265	0.100
Head height:head width	46	–0.085	–0.174
Ex to Me:AL to Me	46	–0.105	–0.151
Tr to Ex:Ex to AL	46	–0.126	0.032
Ex to Ch:Ex to AL	46	0.038	0.099
AL to Me:Ch to Me	46	0.022	–0.096

Table 6 Correlation between change in difference from phi and change in esthetic ratings for ratios determined from lateral cephalograms

Ratio	n	Correlation coefficient: Percentage change	Correlation coefficient: Numeric change
Pm to Xi:Xi to Co	46	0.367*	0.253
N to CC:CC to Ar	46	0.068	0.049
ANS to PNS:PNS to posterior border of mandible	46	0.243	0.156
A to anterior border of mandible:anterior border of mandible to pharynx	46	0.066	0.115
Or to Ptv:Ptv to glenoid fossa	46	0.073	0.192
CC to GN:CC to GO	46	0.206	0.059
Gn to ANS-Xi line: ANS-Xi line to CC	46	0.185	0.119
Pm to A:A to FH	46	0.034	0.068
Me to incisive canal: incisive canal to Ex	46	–0.151	–0.177
Pm to Ii:Ii to A	46	–0.139	–0.170

*$P < .05$.

Table 7 Correlation between change in difference from phi and change in esthetic ratings for ratios determined from frontal photos

Ratio	n	Correlation coefficient: Percentage change	Correlation coefficient: Numeric change
Ex to Me:Tr to Ex	46	0.196	0.204
Tr to AL:AL to Me	46	0.393†	0.345*
Me to AL:AL to Ex	46	0.159	0.134
Ex to Ch:Ch to Me	46	0.219	0.277
Ex to AL:AL to Ch	46	–0.016	–0.084
Me to Ch:Ch to AL	46	0.079	0.164
Head height:head width	46	0.137	0.022
Ex to Me:AL to Me	46	0.181	0.144
Tr to Ex:Ex to AL	46	–0.275	–0.168
Ex to Ch:Ex to AL	46	0.185	0.255
AL to Me:Ch to Me	46	0.003	0.122

*$P < .05$; †$P < .01$.

would be in the divine proportion in beautiful faces. Some individual variation, however, is worth considering. For example, in one patient, 18 of the 21 measured ratios moved toward phi, with only 1 moving away and 2 remaining unchanged. However, this patient was ranked only 21st for improvement in esthetics, with a 20% change (39 to 46.8). In 6 patients, 14 ratios (the second highest number) moved toward phi; however, the rankings of their esthetic change ranged from first (ie, the patient with the greatest improvement) to 41st. The patient with the fewest number of ratios moving towards phi (ie, 2) had the second lowest esthetic improvement (a worsening of appearance by 8.8%). However, in the patient with the lowest improvement score (–18%), 8 ratios moved towards phi. Finally, in 29 of 46 patients in the total sample, more ratios moved away from the divine proportion than toward it. Examples of individual cases are presented in Figs 5 to 7.

These results clearly differ from those of Ricketts' analysis from both lateral cephalograms and photographs. It seems that Ricketts developed the golden ratios from a variety of sources, although the soft tissue ratios were determined after examination of the photos of 10 fashion models.[35,36] The hard tissue ratios were compiled from a composite of 30 Peruvian patients (the radiographs of whom Ricketts[35] described as the most beautiful he had ever seen) as well as "normal" subjects from his own research sample and from the universities of Michigan, Pennsylvania, and Iowa.[36] There may be a subtle difference between using a sample of above-average beauty (ie, models) and a sample that is described as "normal" based on a description of their occlusions. It is not clear whether Ricketts was suggesting that all patients with normal occlusal and skeletal relationships, and hence showing (in theory) cephalometric ratios in the divine proportion, should also possess beautiful facial appearances and

Figs 5a to 5d *(Left)* Pretreatment and *(right)* posttreatment frontal and lateral photographs of the patient ranking fourth in esthetic improvement. Fourteen of the 21 measured ratios in this patient moved toward the divine proportion.

Figs 6 and 7 These photographs illustrate the variability seen in the study. In both patients, 8 ratios moved towards the divine proportion. However, the patient shown in Figs 6a to 6d was ranked 23rd in order of esthetic improvement (an improvement of 8.3 points), while the patient in Figs 7a to 7d ranked 46th (a worsening of 7.5 points).

Figs 6a to 6d

Figs 7a to 7d

exhibit soft tissue ratios in the divine proportion. In contrast to the present study, therefore, it would seem that Ricketts did not attempt to find golden proportions in both the hard and soft tissues of the same sample of patients. Ricketts did suggest that the divine proportions provide formulas by which orthognathic surgery can be planned, and in 1991, he did indeed describe 2 cases in which orthognathic surgery had been planned using the divine proportions.[40] However, the results of the present study have shown that not only did the measured ratios often move away from the divine proportion rather than toward it, but that an improvement in esthetics often took place, even when a majority of the proportions were further away from the golden ratio after surgery. It could be argued by the proponents of the use of the divine proportion that, had surgery been planned for the patients in this sample using the divine proportion, their esthetic improvements might have been greater. A future study may be undertaken in which video-imaging of potential postsurgical appearance is performed, first with traditional cephalometric planning methods and then again using the divine proportion. The 2 resulting images could then be rated to determine which method was more likely to result in an accurate representation of the actual surgical result.

Only a few other studies involving attempts to repeat Ricketts' findings have been published. Nakajima and Yanagisawa,[41] for instance, attempted to find golden proportions in frontal facial photographs of Japanese Class II and Class III patients, although it was unclear why this sample was chosen. Rather than the divine proportion, they found that the ratio of 1.143 (the square root of 2):1 predominated.[42] They also found this same ratio in a sample of Japanese models. In contrast, Kawakami et al,[43] in a sample of 30 Japanese men and 30 women, found that while several of the soft tissue ratios were in the divine proportion, others were not. Moss et al[44] used 3-dimensional techniques to evaluate facial esthetics, measuring various widths within the face, and found none to be in the divine proportion.

The rating of facial attractiveness will always be somewhat subjective, making it difficult to correlate changes in esthetics with any particular facial measurement. By using laypeople as judges as well as professionals trained in the assessment of facial appearance, we hoped to obtain as realistic a rating of beauty as possible. This method was consistent with that of Farkas.[45] While 10 of the 46 patients were rated as actually having a worsened appearance after surgery, these negative changes were very small, with the highest being only 18%, or a drop from an average rating of 41 to 33. These small negative changes should perhaps be better interpreted as a lack of any real facial change as a result of surgery. The worsening in facial esthetics (and, for that matter, the improvement in some cases) may be a reflection of factors other than the changes resulting from surgery, and in a retrospective study such as this, it is not possible to control such things as facial makeup and hairstyles, which may also influence esthetic judgments.

In planning for the present study, the statistical assessment of changes in esthetic ratings required some consideration. It was decided to provide this assessment in 2 ways, first as a percentage change and again as the actual numeric change. In theory, these 2 methods could have provided quite different results. A patient whose esthetic rating went from 1 to 4, for instance, would have shown a 300% change, greater improvement than any case in this study. However, the numeric change from 1 to 4 (ie, 3) would only have been placed 32nd in order of esthetic improvement. With a numeric change of only 3, one might not have expected much clinically recognizable change and hence little change in the values of the measured proportions. However, a 300% change would have suggested great improvement. Table 3 shows that there was, in fact, good correlation between the percentage changes and the numeric changes found in this study. The patients with the 3 greatest percentage improvements also showed the 3 greatest numeric improvements. Furthermore, correlations between the esthetic improvement and changes in the difference from

phi for the measured ratios were performed twice, once using the percentage change and again using the numeric change. No significant correlations were found in either case.

In reviewing the literature, it is obvious that few studies have dealt with changes in facial esthetics. In one study, Barrer and Ghafari[46] assessed profile silhouettes before and after treatment, assessing these only as either "satisfactory" or "unsatisfactory." Lundstrom et al[47] used orthodontists, orthodontic graduate students, laypeople, and artists to rate changes in facial esthetics in subjects from age 12 to age 18. They used a scoring system of 1 to 5, with 1 representing very attractive and 5 representing very disharmonious. The change in esthetics was simply taken as the number of categories that each case moved up or down the scale. The same system was used by Kerr and O'Donnell.[48] Dunleavy et al[49] used a variety of judges to assess the effects of orthognathic surgery. In their study, pre- and posttreatment photographs were shown to the judges at the same time. Those subjects who were determined to show changes in appearance were ranked from most to least improved. Only 19 patients were studied, however. Phillips et al[37] pointed out that the number of patients chosen to be ranked might differ from judge to judge. The method used by Phillips et al[37] was similar to that used in this study. Pre- and posttreatment frontal and profile photographs were shown together to different panels of judges, who each recorded their esthetic preferences on the 100-mm visual analog scale. The numeric change in esthetics in that study was used, rather than a percentage change. Their results were handled differently, however, as the purpose of their study was to evaluate the effects of 2 different treatment modalities, rather than simply to assess the esthetic changes occurring within a treatment group.

The use of the visual analog scale was based on the work of Howells and Shaw[50] and several studies by Phillips and others.[37–39] All these authors had stated that the visual analog scale was popular with the judges, allowing ratings to be given quickly and providing more flexibility than numeric or equal-appearing interval scales. It also allows the ratings to be interpreted as continuous variables. However, Howells and Shaw[50] stated that it is unlikely that judges are able to actually discriminate and record their beliefs with the same degree of precision that the scale would be capable of recording. This would then result in a statistically "noisy" system. According to Aitken,[51] the visual analog system has another limitation as well. Two judges may place a mark at the same point, for instance, without actually feeling the same way about a particular image. Phillips et al[38] also considered that the distribution of ratings might not be the same for all judges, because some may neglect certain portions of the scale. To overcome this problem and to decrease the statistical noise associated with the visual analog method, they first converted the raw scores from the visual analog scale to a ranking scale, with patients ranked from most esthetic to least esthetic. This transformation was not undertaken in this study, as it was necessary to actually obtain numeric values for changes in esthetics to search for a correlation between the degree of esthetic improvement and the amount of movement in each ratio toward phi. Statistical analyses in this and in other studies have shown a reasonably high intrarater reliability for the visual analog scale.

Conclusions

Taking into account the limitations of any cephalometric and facial measurement study, the following conclusions can be made.

1. The measurements that Ricketts[35,36] and Ghyka[29] suggested should be in divine proportion in beautiful faces are just as likely to move away from this ratio as toward it following combined orthodontic/orthognathic surgical treatment, especially if treatment is not planned according to the divine proportion.

2. There seems to be no correlation between esthetic rating and the divine proportion in various facial and cephalometric ratios, either before or after treatment.
3. There seems to be no correlation between the change in esthetic rating as a result of treatment and changes in the values of the measured ratios.
4. The visual analog scale is a useful method for recording judgment of facial attractiveness.
5. Since it seems to be possible for beautiful faces not to exhibit ratios in the divine proportion, and vice versa, if the divine proportions are to be used in orthodontic/orthognathic surgical planning, they should be used only as general guides alongside other well-established treatment planning methods.

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