Radiological Analysis of Human Hand in Terms of Artistic Anatomy

Artistik Anatomi Açısından İnsan Elinin Radyolojik Analizi

Ali YILMAZ, MD,[a]
Banu ALICIOĞLU, MD,[b]
Necdet SÜT,[c]
Enis ULUÇAM, MD,[a]
Selman ÇIKMAZ, MD[a]

Departments of
[a]Anatomy,
[b]Radiology,
[c]Bioistatistic,
Trakya University Faculty of Medicine,
Edirne

Geliş Tarihi/*Received:* 25.11.2008
Kabul Tarihi/*Accepted:* 24.04.2009

Yazışma Adresi/*Correspondence:*
Ali YILMAZ, MD
Trakya University Faculty of Medicine,
Department of Anatomy, Edirne,
TÜRKİYE/TURKEY
ayz51@yahoo.com

ABSTRACT Objective: The hands are one of the most conspicuous parts of the body. The aim of this study was to investigate the relationship between the bones that comprise the hands and their aesthetic importance in terms of the Fibonacci series. **Material and Methods:** In this study, which was designed retrospectively, 123 digital hand roentgenograms of adult patients were reviewed. Each finger was measured in terms of metacarpal, proximal, middle, and distal phalangeal lengths by using a digital caliper. The proximal phalangeal length was subtracted from the sum of the lengths of the middle and distal phalanges and the metacarpal length was subtracted from sum of the lengths of the proximal and middle phalanges, to investigate the conformity to Fibonacci sequence. The Bland-Altman method was used to evaluate the measurements. **Results:** There is a mathematical harmony between all finger bones in terms of the Fibonacci sequence. The first, second, and fifth metacarpals conform to the Fibonacci sequence; however the third and fourth metacarpals do not. **Conclusion:** It can be easily proven that all of the bones that form fingers are in accordance with the Fibonacci sequence. These results convince us that Fibonacci sequence can be used for the reconstruction of human hand after a serious trauma or congenital anomalies.

Key Words: Anatomy artistic; radiography; hand; finger phalanges; anthropometry

ÖZET Amaç: Eller vücudun en fazla dikkat çeken kısımlarındandır. Çalışmamızın amacı eli oluşturan kemikler arasındaki ilişkiyi ve Fibonacci serisi açısından estetik önemini incelemektir. **Gereç ve Yöntemler:** Retrospektif tasarımda planlanan çalışmamızda, 123 yetişkin hastanın ön-arka el grafisi incelendi. Her bir parmakta metakarpal, proksimal, medial ve distal falanks uzunlukları dijital kumpas ile ölçüldü. Proksimal falanks uzunlukları distal ve medial falanksların toplam uzunluklarından, metakarpallerin uzunlukları ise proksimal ve medial falanksların toplam uzunluklarından çıkartılarak Fibonacci serisine uygunlukları araştırıldı. Ölçüm sonuçlarımız, Bland Altman metoduyla değerlendirildi. **Bulgular:** Parmakları oluşturan tüm kemikler arasında matematiksel olarak Fibonacci serisi ile uyumun olduğunu söyleyebiliriz. Birinci, ikinci ve beşinci metakarpaller Fibonacci serisine uygunluk göstermektedir; ancak üçüncü ve dördüncü metakarpaller göstermemektedir. **Sonuç:** İnsan elini oluşturan kemikleri, uzunlukları açısından Fibonacci serisiyle ilişkilendirmenin mümkün olabileceğini söyleyebiliriz. Bu sonuçlar, insan elinin ciddi travma ya da konjenital anomalilerinin rekonstrüksiyonunda Fibonacci serisinden faydalanılabileceğini ortaya koymaktadır.

Anahtar Kelimeler: Artistik anatomi; radyografi; el; parmak falanksları; antropometri

Turkiye Klinikleri J Med Sci 2010;30(2):690-7

The human hand is a symbol of beauty and also an indicator of character from the perspective of its shape and function.[1] Thus, many patients not only want the surgeons to repair the function of their hands, but they also want their hands to look beautiful.[2] Throughout history, many artists and philosophers searched for a magical mathematical formula that could explain beauty; the search ended in a formula called "the golden mean."[3,4] Although there is no written document about the origin of this numerical value, there are many references to it throughout history.[5,6] The golden mean is generally attributed to Pythagoras and Plato, but it is also thought to be connected to logarithmic and equiangular spirals and the Fibonacci sequence.[7,8]

The Fibonacci sequence was first described by Leonardo Pisano Bigollo (also known as Fibonacci) in his book *Liber Abaci* published in 1208. With this book, Fibonacci tried to introduce the numeration decimal that also includes zero to the intellectually dormant Europe. In the last section of his book, he put forward a riddle-like problem about the reproduction of rabbits in a confined area. This riddle, which was like a problem, points out an arithmetical sequence, resulting in a particular ratio. Each new number in the series was simply the sum of two before it (1, 1, 2, 3, 5, 8, 13....). The ratio of two successive numbers approximates a 1.62 continuing value (1; 2; 1.5; 1.60; 1.625; 1.615......). After the first twelve numbers, this numerical value can be fixed to 1.618 when the numbers are rounded up.[5,9] This irrational value is alternately called "the golden mean", "golden ratio", "golden section" or Fibonacci sequence, and is used in many works of architecture, music, art and sculpture.[9,10] However these numbers and ratios seemed to be used by artists intuitively. Leonardo da Vinci, however, used these values deliberately in his experiments. For example, he designed the drawing of Luca Pacioli's book *The Divina Proportione*, in which there was a profile showing the golden mean of the human face. At the beginning of twentieth century, Le Corbusier mentioned the proportions of the human body, in his study known as "Modular".[4,10]

Today, in the medical field, as well as in anatomy, there are many clinical branches such as plastic reconstructive and esthetical surgery which consider the human body as an artistic object. However, current studies mostly deal with the face and have neglected the other parts of the body. However, like the face, the hands attract the most attention and are difficult to hide.

The aim of this study is to investigate the relation between the bones that form the hands and the Fibonacci sequence. We present the existence of such a ratio based on scientific data in the esthetical view of the human body.

MATERIAL AND METHODS

Posteroanterior radiograms of the hands of patients who had applied to Trakya University Medical School Hospital between February 1 and March 25 of 2008 were examined. All X-rays were examined by an experienced muscle-skeleton radiologist and an anatomist at a general-purpose Polystar Siemens workstation. Cases in whom bone development had not been completed, patients with congenital and developmental dysplasia, metabolic illnesses that affect bones, traumatic deformations, surgical operations, or unsatisfactory radiograms were not taken into consideration. Measurements were performed in radiograms of 123 patients (66 males, 57 females) with a mean age of 47,80±14,99.

Although this study was designed retrospectively, ethical approval was obtained from the local Ethical Review Committee of the Faculty of Medicine. The reason for planning a retrospective study was to avoid needless radiation exposure to the patients.

To have more accurate measurements and to clarify the anatomical structures better, the shots were enlarged. Metacarpal (first metacarpal [mc1], second metacarpal [mc2], third metacarpal [mc3], fourth metacarpal [mc4], fifth metacarpal [mc5]), proximal phalangeal (proximal phalanx of the thumb [pp1], proximal phalanx of the index finger [pp2], proximal phalanx of the middle finger [pp3], proximal phalanx of the ring finger [pp4], proximal phalanx of the little finger [pp5]), middle phalangeal (middle phalanx of the index finger [mp2], middle phalanx of the middle finger [mp3], middle phalanx of the ring finger [mp4], middle phalanx of the little finger [mp5]), and distal phalangeal (distal phalanx of the thumb [dp1], distal phalanx of the index finger [dp2], distal phalanx of the middle finger [dp3], distal phalanx of the ring finger [dp4], distal phalanx of the little finger [dp5]) lengths were measured between the distal and proximal tips of the metacarpals and phalanges by using digital caliper.

The differences between proximal phalangeal lengths (pp2, pp3, pp4, pp5) and the sum of the distal and middle phalangeal lengths of each finger (the sum of distal and middle phalangeal lengths of index finger [f2], the sum of distal and middle phalangeal lengths of middle finger [f3], the sum of distal and middle phalangeal lengths of ring finger [f4], the sum of distal and middle phalangeal lengths of little finger [f5]), except the thumb, were measured. Similarly, the differences between the lengths of metacarpals (mc2, mc3, mc4, mc5) and the sum of proximal phalangeal and middle phalangeal lengths (sum of proximal phalangeal and middle phalangeal lengths of index finger [f2a], sum of proximal phalangeal and middle phalangeal lengths of middle finger [f3a], sum of proximal phalangeal and middle phalangeal lengths of ring finger [f4a], sum of proximal phalangeal and middle phalangeal lengths of little finger [f5a]) were calculated (Fig. 1). Owing to the absence of middle phalanx in the thumb, the difference between the first metacarpal (mc1) and the sum of distal (dp1) and proximal phalangeal lengths of first finger were calculated to investigate the conformity to Fibonacci sequence.

STATISTICAL ANALYSIS

Bland & Altman Method

The Bland & Altman plot is a statistical method to compare two measurements techniques. In this graphical method, the differences (or alternatively the ratios) between the two techniques are plotted against the averages of the two techniques. Horizontal lines are drawn at the mean difference, and at the limits of agreement, which are defined as the mean difference plus and minus 1.96 times the standard deviation of the differences. The Bland-Altman method was used in evaluation of the nine parameters; one of the thumb (f1-m1), two parameters of each of the other fingers (f2-pp2, f2a-m2, f3-pp3, f3a-m3, f4-pp4, f5-pp5, and f5a-m5). In the Bland-Altman method, to be able to talk about harmony, the 95% confidence interval (d ± 1.96 SD) should include zero and the distribution of the values should be within confidence limits as much as possible. [11]

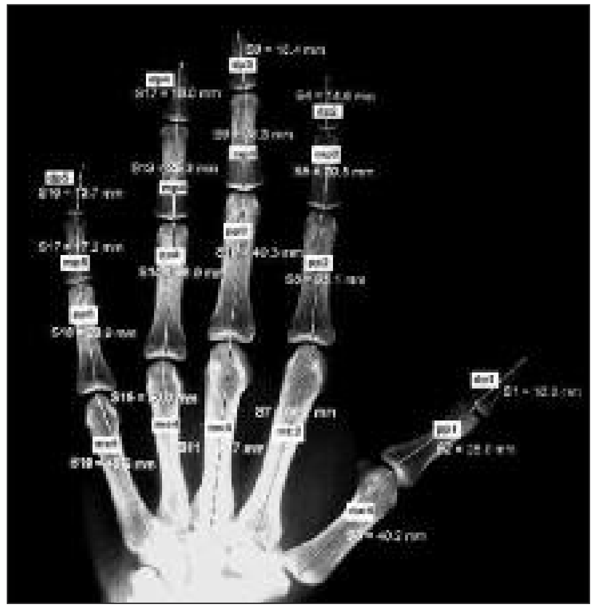

FIGURE 1: PA radiogram of a hand. Bone lengths identified by the name of the field used for statistical analysis. pp- proximal phalanx; dp-distal phalanx; mp-middle phalanx; mc-metacarpal; Thumb-1;Index finger- 2;Middle finger-3; Ring finger -4; Little finger -5.

TABLE 1: Descriptive statistics of difference values.

			%95 Confidence Interval	
Differences	Mean	SD	Lower Limit	Upper Limit
f1-m1	4.7	2.6	-0.4	9.8
f2-pp2	-0.3	2.3	-4.6	4.1
f2a-m2	-5.3	2.8	-10.8	0.1
f3-pp3	1.3	2.3	-3.3	6.0
f3a-m3	6.3	3.3	0.1	12.7
f4-pp4	2.9	2.1	-1.2	7.0
f4a-m4	8.9	2.8	3.6	14.2
f5-pp5	1.6	2.5	-3.3	6.5
f5a-m5	-3.7	2.7	-9.0	1.6

RESULTS

The values obtained by the subtraction of proximal phalangeal and metacarpal lengths from the sum of

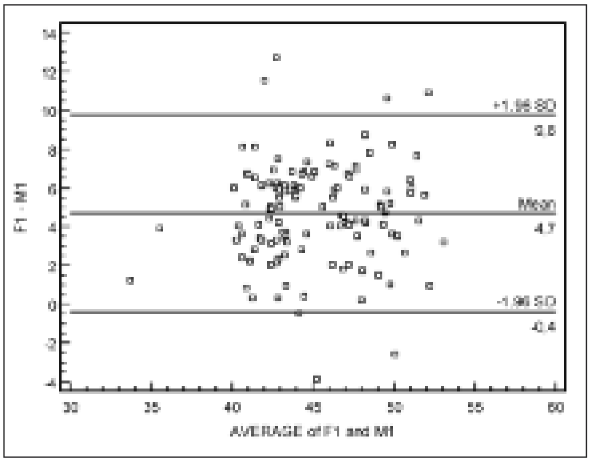

FIGURE 2: Distribution graph of f1-m1 average against difference value (Bland and Altman).

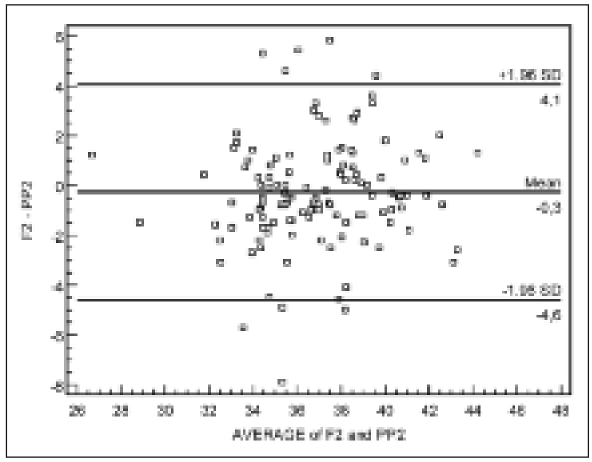

FIGURE 3: Distribution graph of f2-pp2 average against difference value (Bland and Altman).

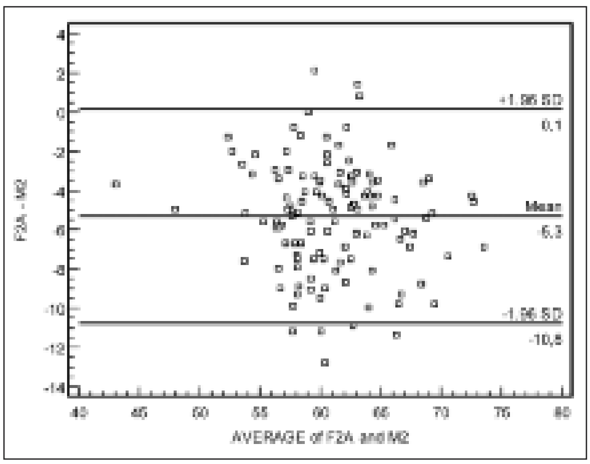

FIGURE 4: Distribution graph of f2a-m2 average against difference value (Bland and Altman).

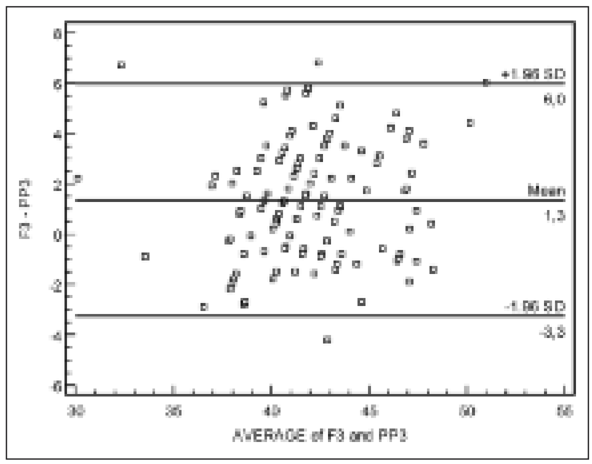

FIGURE 5: Distribution graph of f3-pp3 average against difference value (Bland and Altman).

two previous bone lengths are shown in Table 1. Distribution graphics of each parameter according to Bland-Altman analysis can be found in Figs. 2-10.

In the examination of f1-m1, f2-pp2, f2a-m2, f3-pp3, f4-pp4, f5-pp5, and f5a-m5 distribution graphics, it can easily be seen that all graphics included zero and are in harmony with the Fibonacci sequence.

When the Table 1 is subjected to scrutiny, it can be seen that f2-pp2 is the most harmonious parameter with -0.3 ± 2.3 difference value (95% confidence interval: -4.6 to 4.1) followed by f3-pp3 and f4-pp4 couples, respectively. Discordant parameters were f4a-m4 with 8.9 ± 2.8 difference value

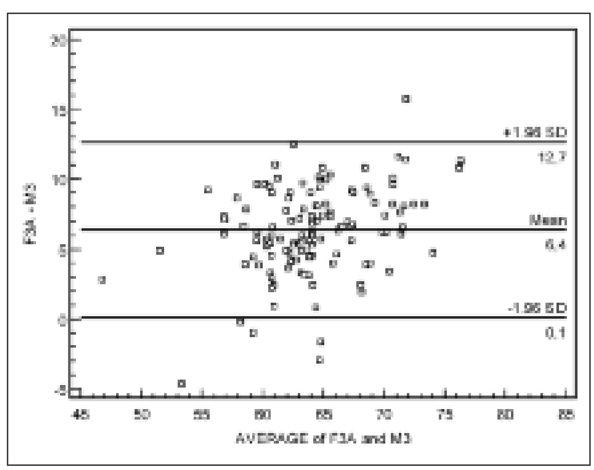

FIGURE 6: Distribution graph of f3a-m3 average against difference value (Bland and Altman).

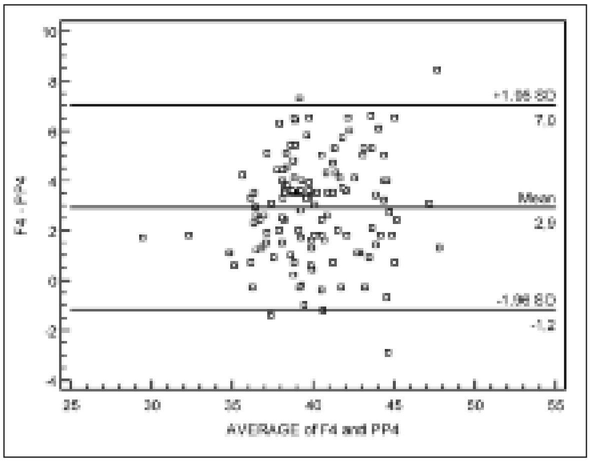

FIGURE 7: Distribution graph of f4-pp4 average against difference value (Bland and Altman).

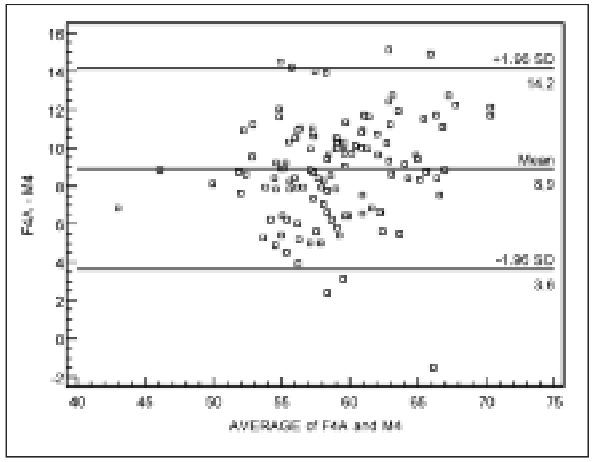

FIGURE 8: Distribution graph of f4a-m4 average against difference value (Bland and Altman).

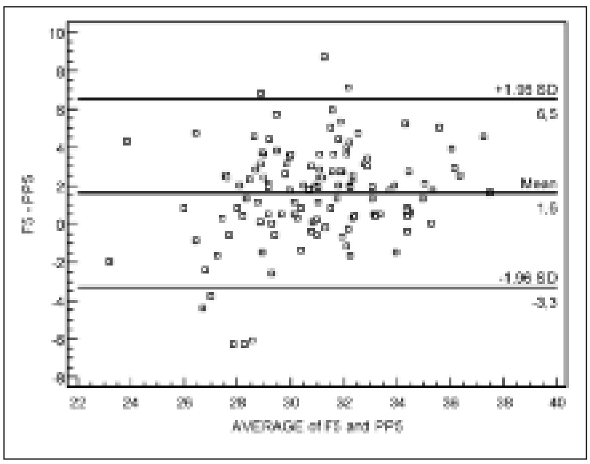

FIGURE 9: Distribution graph of f5-pp5 average against difference value (Bland and Altman).

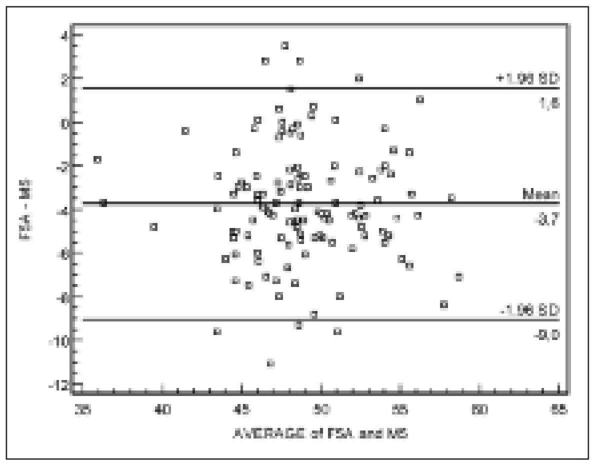

FIGURE 10: Distribution graph of f5a-m5 average against difference value (Bland and Altman).

(95% confidence interval: 3.6–14.2), and f3a-m3 with 6.3 ± 3.3 difference value (95% confidence interval: 0.1–12.7).

When proximal phalangeal lengths were taken into consideration, it was seen that the value of index finger was below zero in most of the patients. Middle, ring and little finger values of the subjects were above zero in general. The difference values were determined as equal to zero in index fingers of four patients and in ring finger and little finger of two patients.

In the evaluation of metacarpals, it was seen that the difference of second metacarpal was generally below zero, whereas the values of the other fingers were above zero. In first and fifth metacarpals of one subject, the difference value was equal to zero, showing perfect harmony.

DISCUSSION

According to the results of this study, it is possible to say that distal, middle, and proximal phalangeal lengths of all the subjects are in harmony with Fibonacci sequence. However, the harmony between middle and proximal phalangeal lengths was observed only in the second and the fifth metacarpals, when the metacarpals' lengths were substracted from the sum of middle and proximal phalangeal lengths.

This number sequence that is thought to be the foundation of human aesthetics has attracted scientists' interest since ancient times and is recognized in many animate and inanimate objects.

After becoming aware of the spiral of florets in the daisy and by the leaves around its stem, which follow precisely the Fibonacci series in mathematics, Turing and his students wrote several papers addressed to the problem of leaf arrangement (phyllotaxis), which continues to exercise many biologists today. Turing's paper has inspired a current generation of mathematical modeling of spatial patterns in living organism. [12]

In his study "On Growth and Form", Thompson pointed out how the Fibonacci sequence underlies many natural forms such as the spiraling Nautilus shell, the arrangement of scale rows on Norway spruce cones, cellular structure, arrangements of leaves and animal horns. Actually, Thompson has demonstrated that there is a lawful underlying mathematical structure to forms based on the golden section and Fibonacci sequence.[13,14] Additionally, Carson, Arnheim, and Naylor stated that spirals of growing flowers were related to the Fibonacci sequence.[10,15,16] Fensom, in his article, talked about the possibility that human evolution stops when it reaches the golden number.[17] Yamagishi et al., in his study, put forward the compatibility between the human gene nucleotide arrangement and the Fibonacci sequence.[18] Moreover, McWhinnie studied the golden mean of human growth, biology, and architecture.[14] The first book in history defining human proportions is Polycleitus' *Canon*. According to Tobin, Polycleitus mentioned several ratios in his book.[19]

The application of the golden ratio to dental aesthetics was first documented by Lewin in 1978 who also explained its history and mathematics. He also explained regarding the association of the proportion with an aesthetically pleasing dentition and smile.[20]

Esthetical dentists have used many such formulas while reconstructing the teeth to obtain a "nice smile." Lombardi claimed the existence of golden mean between the human teeth as well.[21]

Preston studied the relationship of the golden ratio in maxillary dentition and found a golden ratio between the perceived width of the maxillary central and lateral incisors.[22]

Mack discussed the importance of treating the dentition according to the face based on the golden ratio. He stated that the lower one –thirds of the face significantly influences the facial appearance and warned regarding potential complications occurring in facial aesthetics when only mounted casts were used for diagnosis.[23]

Robert Ricketts, an orthodontist, discussed the golden ratio in ideal face proportions by using his self-designed tool "the golden dividend."[24] Likewise, Stephan Marquart, who has performed many important studies on the ratios of human aesthetic and symmetry, designed a series of beauty masks based on the golden ratio.[3]

Jefferson illustrated many golden ratio diagrams and computer generated photographs providing an ideal picture of the complete head and supported his work with cephalometric tracings.[25]

Littler observed an arithmetical relation among the bones that shape the hand and said that finger movements form equiangular spirals.[8] Additionally, Powell related the rumba dance and music to the Fibonacci sequence.[9] Twentieth-century music has been directly related to the Fibonacci sequence by Kramer, Manuel and Santiago, and Walker stated that the golden mean could be used in calculating electrical circuit resistance.[26-28] Nevertheless, there are many studies that contradict the research about the golden ratio and Fibonacci sequence.[29]

During a review of the literature, we came across many studies on the lengths of hand bones, ratios among the fingers and the factors affecting these ratios. We were able to find two articles in which the Fibonacci sequence and the golden ratio of the length of fingers were discussed. In one of these two studies Park et al. worked on 100 hand-graphics and in the other study Hamilton and Dunsmuir worked on 197 graphics.[30,31] Although both of these studies had used the same parameters, the points used in the measurements differ. Hamilton and Dunsmuir measured the distance between the rotation centers of the hand bones. On the other hand, Park et al. measured the distance between the mid-points of joint cavities. In the present study, we found the actual bone length by measuring the distance between the base and distal tip points of metacarpals and phalanges.

Except for the thumb, where proximal phalangeal length was subtracted from the sum of distal and middle phalangeal lengths, we determined that the "0" value was in the 95% confidence interval in each finger. Likewise, when the metacarpal length was subtracted from the sum of proximal and middle phalangeal lengths of f2a-m2 and f5a-f5, we observed that the "0" value was in 95% confidence interval for each finger. The thumb, which has no middle phalanx revealed "0" value in 95% confidence interval when its metacarpal length was subtracted from the sum of proximal and distal phalangeal lengths.

Unlike the present study, Park et al. could not find any correlation to the Fibonacci sequence in any of the fingers. In their study, Hamilton and Dunsmuir did not look for the Fibonacci sequence, but looked for the golden ratio, which was thought to be the result of the Fibonacci sequence. They could not prove the existence of the golden ratio.

CONCLUSION

It can be suggested that all of the bones that form the fingers were in harmony with the Fibonacci sequence mathematically. Similarly, the existence of this mathematical sequence can be seen in f1-m1, f2a-m2, and f5a-m5. However, because of not having any "0" value in the 95% confidence interval, f3a-m3 and f4-m4, do not conform to the Fibonacci sequence.

There are many studies in which some numbers and ratios in nature are used by artists throughout history. In this study, we claim that it is possible to relate the bones forming the human hand with the Fibonacci sequence. As a conclusion, the Fibonacci sequence can be used as an alternative option in reconstruction of the human hand after a serious trauma or in case of congenital abnormalities.

REFERENCES

1. Gürcan S, Adıyaman S. [Anatomy and kinesiology of the hand]. Turkiye Klinikleri J PM&R-Special Topics 2008;1(1):1-9.
2. Jakubietz RG, Jakubietz MG, Kloss D, Gruenert JG. Defining the basic aesthetics of the hand. Aesthetic Plast Surg 2005;29(6):546-51.
3. Marquardt SR. Dr. Stephen R. Marquardt on the Golden Decagon and human facial beauty. Interview by Dr. Gottlieb. J Clin Orthod 2002;36(6):339-47.
4. Seghers MJ, Longacre JJ, DeStefano GA. The golden proportion of beauty. Plast Reconstr Surg 1964;34(4):382-6.
5. Peterson RG. Critical calculations: measure and symmetry in literature. PMLA 1976;91(3):367-75.
6. Plug C. The golden section hypothesis. Am J Psychol 1980;93(3):467-87.
7. Bell ET. The golden and platinum proportions. National Mathematic Magazine 1944; 19(1):21-6.
8. Littler JW. On the adaptability of man's hand (with reference to the equiangular curve). Hand 1973;5(3):187-91.
9. Powell NW. Fibonacci and the gold mean: rabbits, rumbas, and rondeaux. J Music Theor 1979;23(2):227-73.
10. Arnheim R. A review of proportion. J Aesthet Art Critic 1955;14(1): 44-57.
11. Bland JM, Altman DG. Statistical methods for assessing agreement between two methods of clinical measurement. Lancet 1986; 1(8476):307-10.
12. Wan Ho M. Reanimating nature: the integration of science with human experience. Leonardo 1991;24(5):607-15.
13. Neperud RW, Serlin RC. The fibonacci sequence: proportional and semantic bases of children's aesthetic preferences. Stud Art Educ 1984;25(2):92-103.
14. McWhinnie HJ. A biological basis for the golden section in art and design. Leonardo 1989; 22(1):61-3.
15. Carson J. Fibonacci numbers and pineapple phyllotaxy. The Two-Year College Mathematics Journal 1978;9(3):132-6.
16. Naylor M. Golden, $\sqrt{2}$, and π Flowers: A Spiral Story. Mathematics Magazine 2002;75(3):163-72.
17. Fensom DS. The golden section and human evolution. Leonardo 1981;14(3):232-3.
18. Yamagishi ME, Shimabukuro AI. Nucleotide frequencies in human genome and fibonacci numbers. Bull Math Biol 2008;70(3):643-53.
19. Tobin R. The Canon of polykleitos. AJA 1975;79(4):307-21.
20. Levin EI. Dental esthetics and the golden proportion. J Prosthet Dent 1978;40(3):244-52.
21. Lombardi RE. The Principles of Visual Perception and Their Clinical Application to Denture esthetics. J Prosthet Dent 1973;29(4):358-82.
22. Preston JD. The Golden Proportion Revisited. J Esthet Dent 1993;5(6):247-51.

23. Mack MR. Vertical Dimension: A Dynamic Concept Based on Facial Form and Oropharyngeal Function. J Prosthed Dent 1991; 66(4):478-85.

24. Ricketts RM. Esthetics, environment, and the law of lip relation. Am J Orthod 1968;54(4): 272-89.

25. Jefferson Y. Skeletal types: key to unraveling the mystery of facial beauty and its biologic significance. J Gen Orthod 1996;7(2):7-25.

26. Kramer J. The fibonacci series in twentieth-century music. Journal of Music Theory 1973; 17(1):110-48.

27. Manuel G, Santiago A. An Unexpected Appearance of the Golden Ratio. The College Mathematics Journal 1988; 19(2):168-170.

28. Walker RC. An electrical network and the golden section. The Mathematical Gazette 1975; 59(409):162-5.

29. Markowsky G. Misconceptions about the golden ratio. The College Mathematics Journal 1992;23(1):2-19.

30. Park AE, Fernandez JJ, Schmedders K, Cohen MS. The Fibonacci sequence: relationship to the human hand. J Hand Surg Am 2003;28(1):157-60.

31. Hamilton R, Dunsmuir RA. Radiographic assessment of the bones of the lengths of the fingers of the human hand. J Hand Surg Br 2002;27(6):546-8.