Original Article

Lateral comparisons using Fishman's skeletal maturation assessment

Abraham N. Safer[a]; Peter Homel[b]; David D. Chung[c]

ABSTRACT

Objective: To assess lateral differences between ossification events and stages of bone development in the hands and wrists utilizing Fishman's skeletal maturation indicators (SMIs).

Materials and Methods: The skeletal ages of 125 subjects, aged 8 to 20 years, were determined with left and right hand-wrist radiographs using Fishman's SMI assessment. Each subject was also given the Edinburgh Handedness Questionnaire to assess handedness. The skeletal ages of both hand-wrist radiographs were analyzed against each other, handedness, chronologic age, and gender.

Results: There were no significant differences overall in right and left SMI scores ($P = .70$); 79% of all patients showed no difference in right and left SMI scores, regardless of handedness, gender, or age. However, when patients were categorized based on clinical levels of SMI score for the right hand-wrist, there was a significant difference ($P = .01$) between the SMI 1-3 group and the SMI 11 group. Subjects in the SMI 1-3 group were more likely to show a left $>$ right SMI score, while subjects in the SMI 11 group were likely to show a right $>$ left SMI score.

Conclusion: Although no significant overall lateral differences in SMI scores were noted, it may be advisable to obtain a left hand-wrist radiograph and/or additional diagnostic information to estimate completion of growth in young surgical patients. (*Angle Orthod.* 2015;85:408–412.)

KEY WORDS: Hand-wrist; Laterality; Skeletal maturation; Diagnosis

INTRODUCTION

One way orthodontists determine a patient's skeletal maturation and assess growth is by obtaining a hand-wrist radiograph during the diagnostic workup. Skeletal maturation in the hand-wrist area has been positively correlated with statural as well as facial growth.[1–4] The method of evaluation used at the Maimonides Medical Center (MMC) Division of Orthodontics and Dentofacial Orthopedics was first described by Fishman[3,5] in the 1980s. This system examines 11 anatomic sites on the phalanges, the adductor sesamoid, and the radius and is organized into a skeletal maturation index (SMI) to determine growth potential and remaining growth of an individual (Figures 1 and 2[3]). Our clinic normally obtains the right hand-wrist radiograph because of the orientation and setup of our imaging system within the radiology room. On the assumption that other orthodontic offices have different arrangements for their radiology equipment, it may be easier for some practitioners to expose the left hand-wrist for this radiograph. We queried Dr Fishman as to which side he uses, and he responded that he conventionally uses the left hand-wrist for this radiograph.

The purpose of this study was to assess lateral differences between ossification events and stages of bone development in the hands and wrists utilizing Fishman's skeletal maturation indicators. Studies involving laterality of the human skeleton are not new; Roche[2] reported real but insignificant differences between the right and left hand-wrists using the Greulich-Pyle standards.[6] That particular method evaluates the number of ossified bones in the hand-wrist area as seen in a hand-wrist radiograph, unlike the ossification events of 11 anatomic sites used in the SMI system. According to a systematic review performed by Flores-Mir et al.,[4] the SMI method is more useful because it decreases the environmental

[a] Chief Resident, Maimonides Medical Center, Department of Dentistry, Division of Orthodontics and Dentofacial Orthopedics, Brooklyn, NY.

[b] Senior Biostatistician, Maimonides Medical Center, Office of Research Administration, Brooklyn, NY.

[c] Program Director, Maimonides Medical Center, Department of Dentistry, Division of Orthodontics and Dentofacial Orthopedics, Brooklyn, NY.

Corresponding author: Dr David D. Chung, Orthodontics Program Director, Maimonides Medical Center, 4303 13th Ave, Brooklyn, NY 11219-1337
(e-mail: dchung@maimonidesmed.org)

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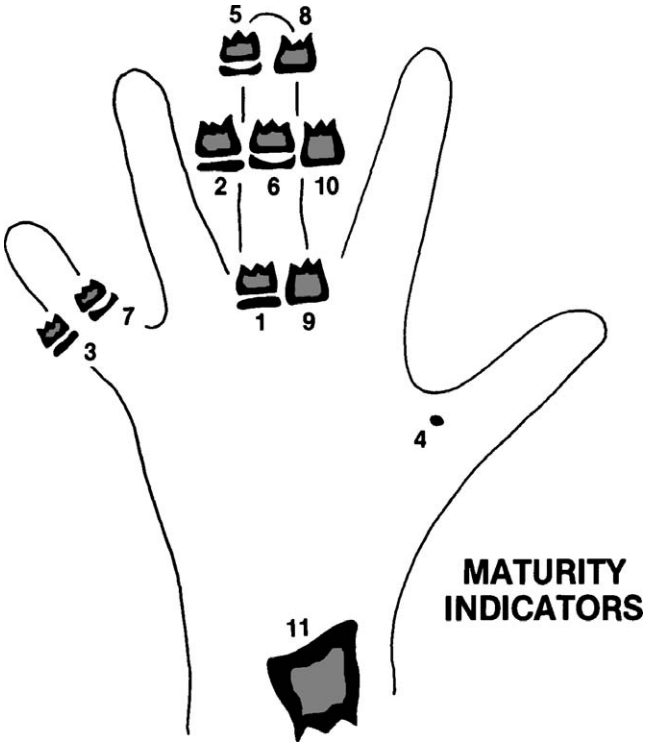

Figure 1. The 11 skeletal maturation indicators (SMIs) of Fishman. Reproduced with permission from The Edward H. Angle Society of Orthodontists.

and racial influences of the sample. To date, no studies have been published that evaluate lateral differences within the SMI system of hand-wrist maturation. If a significant difference exists in maturation between the right and left hand-wrist areas, then the use of only one side would not provide a reliable estimate of skeletal maturation. This becomes of clinical importance when treating patients who are at the threshold of their growth spurt or completing growth. In such instances, to determine the path of and appropriate timing for treatment, more information than a single radiograph of one hand-wrist may be required. Thus, we examined right and left hand-wrist radiographs in subjects to determine whether clinically significant differences existed.

MATERIALS AND METHODS

This was a cross-sectional comparative study involving hand-wrist radiographs taken at the MMC Division of Orthodontics and Dentofacial Orthopedics in Brooklyn, New York. The total sample consisted of 125 subjects: 65 males (52%) and 60 females (48%). The mean age of the subjects was 13.44 $\pm$ 2.56 years (range, 7 years 10 months to 20 years 2 months). Exclusion criteria included any subject with a medical condition that would alter normal growth and development.

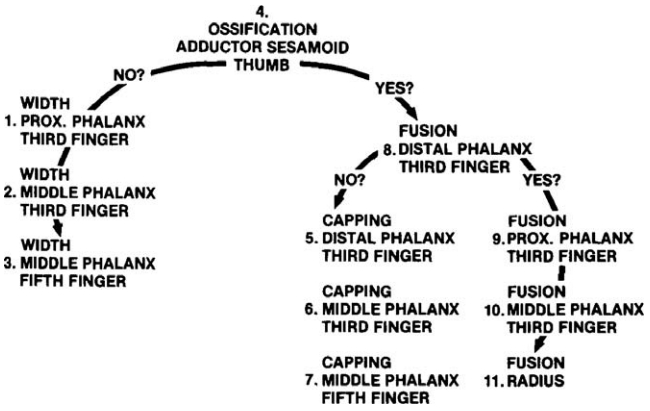

Figure 2. An observational scheme for assessing SMIs on a hand-wrist radiograph. Reproduced with permission from The Edward H. Angle Society of Orthodontists.

A right hand-wrist film was obtained as part of the routine orthodontic radiographic workup at our clinic. Approval was received from the institutional review board at the MMC to acquire a second film of the left hand-wrist from each subject. Informed consent was obtained prior to the enrollment of each subject in the study, at which time the patient was asked to complete the Edinburgh Handedness Questionnaire[7,8] to establish handedness. All hand-wrist radiographs were taken with the Sirona Orthophos XG5 imaging system. Exposure settings were fixed at the manufacturer's recommendation of 9.1 s/64 kV/16 mA, which is equivalent to an effective dose of 0.5 mrem (0.005 mSv). The radiology department at MMC confirmed that this dose is negligible and would pose minimal risk to the study population.

Each subject was assigned a participant number to maintain operator blindness during the study. Right and left hand-wrist radiographs were stored in separate electronic folders and were evaluated in isolation and at different time periods. Similarly, the responses from the Edinburgh Handedness Questionnaire were kept separate from the SMI evaluations.

One investigator evaluated all of the radiographs using the following protocol. Each hand-wrist radiograph was initially evaluated to determine the SMI score of the subject. To determine intraoperator reliability, each radiograph was reanalyzed 2 weeks after the initial evaluation, and a second SMI score was recorded. The two SMI scores were compared, and any discrepancies between them were identified. If the SMI scores did not match, the subject's participant number was written down and the radiographs of that subject were reanalyzed for a third time at least 2 weeks later. The third SMI score always matched either of the previous two recordings and was used as the final SMI score used for that particular subject.

Table 1. SMI Scores by Handedness

Characteristic		Handedness: Right (n = 109)	Left (n = 11)	No Preference (n = 5)	*P* value[a]
Age[b]		13.49 ± 2.62	12.29 ± 1.78	14.84 ± 1.77	.15
Gender[c]	Male	54 (83%)[c]	6 (9%)	5 (8%)	.09
	Female	55 (92%)	5 (8%)	0 (0%)	
Right SMI		7.07 ± 3.10[d]	5.09 ± 3.88	9.20 ± 1.30[e]	.04
Left SMI		7.07 ± 3.05	5.18 ± 3.76	9.40 ± 1.52[e]	.03

[a] Overall *P* value comparing handedness.
[b] Means ± standard deviations.
[c] Frequencies (percentages).
[d] *P* value < .05 comparing right handedness versus left handedness.
[e] *P* value < .05 comparing no preference versus left handedness.

All acquired SMI data were compiled and grouped into four different categories: SMI 1 to 3 for the prepubertal period, SMI 4 to 7 for the circumpubertal period, SMI 8 to 10 for the postpubertal period, and SMI 11 for the completion of growth.

In this study, it was determined that, with an estimated standard deviation of 2.75 for SMI scores, to detect a one-point difference in SMI between right and left hand-wrist radiographs, a minimum of 65 patients would be necessary to obtain at least 80% statistical power, with alpha = .05. Continuous variables were described in terms of means ± standard deviations, whereas categorical data were described in terms of frequency (percent). Chi-square analysis was used to compare gender and handedness as well as discrepancies between right and left SMI scores based on the SMI score for the right hand-wrist. Differences in age between subjects with different handedness were compared with one-way analysis of variance, and a repeated-measures analysis of variance was used to compare differences between right and left SMI scores and gender as a function of handedness. The Pearson correlation coefficient was used to measure the linear relationship between continuous measures, such as right and left SMI scores. Multinomial logistic regression was also done to confirm the pattern of discrepancies between right and left SMI scores based on the actual SMI score of the right hand-wrist. All analyses were performed using IBM SPSS version 20 (IBM Inc, Kerhonkson, NY) and were set at a .05 level of significance.

RESULTS

Of the 125 subjects included in this study, 109 (87%) reported their preferred handedness as "right," 11 (9%) reported their preferred handedness as "left," and 5 (4%) reported no preference. Mean ages and mean right and left SMI scores for each handedness group are reported in Table 1. There were no overall differences in age or gender distribution between the handedness groups ($P = .15$ and $P = .09$, respectively), but there were differences in their SMI scores ($P = .04$ for the right; $P = .03$ for the left). The mean SMI score for both hand-wrists in subjects with left-hand preferences tended to be about 5, the mean SMI score for subjects with right-hand preferences was about 7, and the subjects with no preference had the highest mean SMI score, at about 9.

There were no significant overall differences in mean SMI levels between the right and left sides (6.98 ± 3.19 vs 7.00 ± 3.14, $P = .70$) and there were no differences in SMI levels when stratified by handedness (interaction $P = .54$). This indicated that, although SMI scores differed by handedness, the levels were similar across right and left hand-wrists in each handedness group. In general, the right and left SMI scores were highly correlated with each other ($R = 0.99$, $P < .001$), as depicted in Figure 3.

Despite this, 26 subjects (21% overall) did show a one-point difference between their right and left SMI scores, some in favor of the right and others in favor of the left. Table 2 shows the distribution of differences

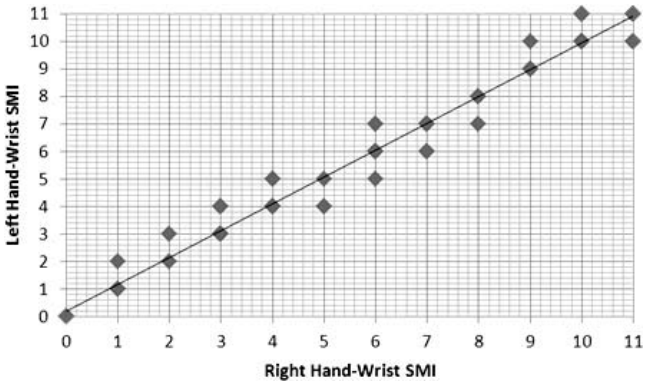

Figure 3. Scatterplot comparing right and left SMI scores for all 125 subjects ($R = 0.99$, $P < .001$).

Table 2. Difference Between Right and Left SMI Scores by Level of the Right Hand-Wrist SMI Score[a]

Right SMI Scores	Right SMI Score – Left SMI Score		
	Left > Right (Diff = −1)	Right = Left (Diff = 0)	Right > Left (Diff = 1)
1 to 3	5 (24%)	12 (76%)	0 (0%)
4 to 7	4 (8%)	41 (80%)	6 (12%)
8 to 10	5 (14%)	29 (83%)	1 (3%)
11	0 (0%)	13 (72%)	5 (28%)

[a] $P = .008$.

between right and left SMI scores (left > right, right = left, and right > left) as a function of the subject's right SMI score. Ninety-nine of the 125 subjects (79%) showed no difference between right and left SMI scores. However, the subjects with the lowest right SMI scores (SMI 1-3) were far more likely to show differences involving the left SMI score > right SMI score rather than right > left SMI scores (24% vs 0%). Those at intermediate levels (SMI 4-7 and 8-10) showed mixed results, with no clear favoring of either left < right or right > left differences. Finally, those at the highest level (SMI 11) were more likely to show right > left than left > right (28% vs 0%), which is virtually the mirror image of the SMI 1-3 group. This pattern was statistically significant ($P = .01$, chi-square; $P = .048$, multinomial logistic regression using actual right hand-wrist SMI scores).

DISCUSSION

When treatment planning orthodontic patients, it is important to determine whether orthopedic and/or surgical modalities are necessary components to accomplish treatment goals. Since the rate of facial growth has been correlated with both statural growth and skeletal maturation[6] and because chronological age is not a good predictor of growth,[9] many orthodontists resort to various radiographic methodologies to help them determine the critical time periods of a patient's growth process. Fishman's SMI hand-wrist analysis is the method of choice used at the MMC Division of Orthodontics and Dentofacial Orthopedics. While some studies have noted a disadvantage in exposing a radiograph of the hand-wrist area and advocate the use of cervical vertebrae maturation staging from an existing lateral cephalogram,[10,11] others have questioned the reliability of the latter.[12,13] Our clinic has found that hand-wrist radiographs are easily implemented, simple to evaluate, and a valuable adjunct to our diagnostic workup.

This study compared right and left hand-wrist films using the SMI system of analysis. Although the overall differences were not significant, our results indicated a statistically significant trend in which, when relating the right hand-wrist data to the differing right and left SMI scores, the left side displayed more advanced growth in the lowest SMI group (SMI 1-3) and the right side showed more advanced growth in the highest SMI group (SMI 11). This discrepancy becomes important when attempting to identify a patient's critical growth period, such as the pubertal growth spurt.[14] If 29% of subjects in the lowest SMI group showed advanced maturation of the left hand-wrist, then the use of a right hand-wrist radiograph may estimate a later timing for peak growth and would risk delaying functional appliance therapy at the optimal time for treatment.[15] Therefore, it may be better to obtain left hand-wrist radiographs so that the pubertal growth spurt can be more accurately estimated when using Fishman's method.[3]

Another and perhaps more prudent implication of our study results involves orthognathic surgical timing in young adult patients on recall for completion of skeletal growth. Mandibular growth is generally considered complete at SMI 11, and it is at this time that the surgical phase of treatment may be initiated. However, our data showed that 28% of subjects in the highest SMI group had advanced maturation of the right hand-wrist. Consequently, it is recommended that the left hand-wrist be used to more accurately estimate the completion of skeletal growth in these patients.

These findings indicate that the ideal design and arrangement for the radiology room and equipment would permit convenient acquisition of the left hand-wrist radiograph. If this cannot be easily achieved, as is the case at MMC, then the right hand-wrist radiograph should be supplemented with additional diagnostic information to more accurately estimate a patient's skeletal maturation.

Finally, our study also demonstrated a trend in which subjects in the left-handed group were confined to a lower age and SMI score compared with subjects in the right-handed or no preference groups. Further studies with larger sample sizes are needed to confirm this finding and to determine whether a conversion of handedness transpires as a person matures.

CONCLUSIONS

- Handedness, gender, and chronologic age do not play a significant role in the differences between right and left SMI scores.
- Although the overall correlation of right and left SMI scores was very high (79%), 24% of subjects in the SMI 1-3 group had a more advanced left SMI score, and 28% of subjects in the SMI 11 group had a more advanced right SMI score.
- It is recommended to use a left hand-wrist radiograph to estimate the completion of skeletal growth.

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