A comparison between radiographic and sonographic assessment of hand and wrist bones for the estimation of skeletal age in the child patient

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ABSTRACT. Aim The purpose of this study was to examine, with a sonographic investigation, the hand and wrist bones of a group of young patients and to compare the results with those obtained with a classical radiographic assessment.

Materials and methods Some 25 subjects, 9 – 18 years of age, who presented problems concerning their short stature or precocious puberty, were evaluated. Each subject was examined by a standard radiographic assessment and by a sonographic investigation with real-time imaging. Sonographic examination was performed on the metacarpus-phalanx articulation of the first finger in order to locate the sesamoid bone. Sonographic examination was also performed on the second and third phalanxes of the third finger and on the distal portion of the radius to evaluate the characteristics of growth cartilage in the area.

Results and Statistics In all the cases where a sesamoid bone was present, this was correctly identified by the sonogram, even up to the initial appearance of its ossification nucleus. Sensitivity, specificity, and diagnostic accuracy were all 100%. The capping phenomenon seen in radiographs was not detected by sonographic investigation in any of the cases. Sonographic evaluation of the fertile cartilage of the third finger distal phalanx demonstrated a sensitivity of 89%, a specificity of 100% and a diagnostic accuracy of 92%. Sonographic evaluation of the radius cartilage showed a sensitivity of 95%, a specificity of 100% and a diagnostic accuracy of 96%.

Conclusion Sonographic evaluation of hand and wrist bones cannot accurately reproduce the results of the classical radiographic evaluation. However, the sonographic investigation may be useful, when integrated in a radiographic investigation.

KEYWORDS: Skeletal age, Hand and wrist, Radiographic examination, Sonographic examination

Introduction

Skeletal age is one of the best indices of biologic maturation [Demirjian et al., 1985; Nicoletti, 1990]. Its knowledge becomes particularly important when treating children around the age of puberty, when numerous diagnostic and therapeutic problems related to growth and development may arise [Bergersen, 1972; Cole et al., 1998].

It is known that skeletal maturation is highly correlated with the maturation of other systems of the body, especially during puberty [Carpenter and Lester, 1993; Sfondrini et al., 1997]. Skeletal age may be assessed by examining different parts of the skeleton, the most common being the hand and wrist, where different types of bone (short, long, flat) are simultaneously present [Hagg and Taranger, 1980; Nicoletti, 1990]. The hand and wrist is composed of a huge number of bones where 29 nuclei of epiphysial ossification appear between 3 months and 12 years of age [Greulich and Pyle, 1959], making it ideal for growth assessment. One other advantage to using the hand and wrist for the assessment of skeletal age is, obviously, the ease of performing radiographs in the area as compared with...
other parts of the skeleton [Hagg and Taranger, 1980].

Knowledge of the patients skeletal age is of particular importance when considering orthognathodontic treatment. This kind of therapy is characterised by two treatment goals: orthopaedic, which aims to reshape the bones of the face, and orthodontic, which aims to reposition dental structures [Fishman, 1979; Nessi et al., 1997].

While the orthodontic goal may be achieved at any age, the orthopaedic goal may only be realised while growth and development are in progress. Once growth has terminated, as in adults, only maxillofacial surgery can reshape and reposition the bones of the face [Houston, 1980; Moyers, 1994]. For this reason, knowledge of the patient’s skeletal age is fundamental in determining the choice of ideal treatment: orthognathodontic therapy, maxillofacial surgery, or simply and exclusively orthodontic therapy.

Orthopaedic goals are best achieved in females from 10 to 14 years of age and in males from 12 to 16 years of age. During this period, four stages of skeletal growth may be identified in hand and wrist radiographs [Fishman, 1982; Sfondrini et al., 1997].

- Appearance of the sesamoid bone at the level of the first phalanx of the first finger. This marks the beginning of the highest growth rate; it is the period where a positive response to orthopaedic therapy is attainable.
- Presence of the capping phenomenon. The epiphysis of the second phalanx of the third finger acquires a particular radiographic appearance; its presence coincides with adolescent growth spurt; maximum response to orthopaedic treatment is most likely to occur at this time.
- Fusion of the epiphysis of the third phalanx. This marks the end of the growth spurt, particularly the growth of the maxillary bone; response to orthopaedic treatment during this stage is poor.
- Complete fusion of the epiphysis of the radius. This marks the end of growth, particularly the growth of the mandible; treatment during this stage will not produce orthopaedic results.

The use of the radiograph for examining hand and wrist bones, and thus assessing skeletal age, has been the standard procedure employed by health professionals for many years. Recently, sonograms have been used for the evaluation of bone tissue in different parts of the body. Even if sonograms of the hand and wrist can prove as effective as radiographs in the assessment of skeletal age, unnecessary exposure to radiation may be avoided [Cattel, 1928; Ruohniemi, 1993; Castriota et al., 1995; Garattini et al., 1998].

The purpose of this study was to compare the results of a sonographic evaluation of the hand and wrist to those obtained with a standard radiographic evaluation.

Materials and methods

The study population consisted of 25 subjects, 14 males and 11 females, between the ages of 9 and 18 years. These children presented orthodontic problems related to delayed or precocious skeletal development. A standard radiographic examination of the left hand and wrist of each patient was performed in projection black palmar. The same hand and wrist was examined by sonogram, using real-time imaging of the latest generation and employing a 7.5 MHz linear probe with a superficial focality, on the same day. Sonographic examination consisted of longitudinal scans of the metacarpus-phalanx articulation of the first finger in order to locate the sesamoid bone. Similar scans were performed in the area of the second and third phalanges of the third finger and on the distal portion of the radius, to detect the presence of growth cartilage.

For statistical purposes, the subjects were divided into two groups, ‘positive’ and ‘negative’, based on the results of their radiographic examination. A subject was classified as ‘positive’ when the sesamoid bone or growth cartilage could be identified radiographically. A subject was considered ‘negative’ when no sign of the sesamoid bone or growth cartilage could be identified in the radiograph.

In analysing the results of the sonographic examination, the subjects were divided again into groups. Based on the results of the radiographic examination, those of the sonographic examination were classified as ‘true positive’, ‘true negative’, ‘false positive’ and ‘false negative’.

The results of the sonographic examination were then compared with those of the radiographic examination and evaluated for sensitivity, specificity and diagnostic accuracy. Sensitivity was calculated as the percentage of ‘positive’ sonograms correctly classified as ‘positive’. Specificity was calculated as the percentage of ‘negative’ sonograms correctly classified as ‘negative’. Diagnostic accuracy was calculated as the percentage of ‘positive’ and ‘negative’ sonograms correctly classified as ‘positive’ and ‘negative’.
**Results**

Radiographs detected the presence of the sesamoid bone in 18 of the 25 subjects (Fig. 1). Growth cartilage was identified radiographically in the distal phalanx of the third finger in 19 children and in the radius in 21 patients (Table 1).

Sonographic examination revealed the presence of the sesamoid bone (Fig. 2), including the initial appearance of its ossification nucleus, in the same number of cases classified as ‘positive’ in radiographic examination.

The absence of the sesamoid bone was noted in the same number of ‘negative’ cases for radiographic examination (Table 2). Thus, sensitivity, specificity,

**FIG. 1 -** Radiographic image revealing the presence of sesamoid bone and growth cartilage. The radiopaque structure medial to the metacarpus-phalanx articulation of the first finger corresponds to the sesamoid bone. The epiphysial growth cartilage at the level of the third finger and of the radius is visible as radiolucent rimae between epiphysis and diaphysis.

**FIG. 2 -** Sonographic image of the ossification nucleus of the sesamoid bone at its initial appearance. It is visible as a small hyperechoic granule in the middle of the hypoechoic area corresponding to the growth nucleus.

<table>
<thead>
<tr>
<th>Sesamoid bone of first finger</th>
<th>Cartilage in distal phalanx of third finger</th>
<th>Cartilage in radial epiphysis</th>
</tr>
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<tbody>
<tr>
<td>Positive</td>
<td>18</td>
<td>19</td>
</tr>
<tr>
<td>Negative</td>
<td>7</td>
<td>6</td>
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</tbody>
</table>

**Table 1 -** Presence of bone and cartilage using standard radiographic assessment in a group of children aged 9 to 16 years.

<table>
<thead>
<tr>
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<th>Cartilage in radial epiphysis</th>
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<tbody>
<tr>
<td>True positive</td>
<td>18</td>
<td>17</td>
</tr>
<tr>
<td>True negative</td>
<td>7</td>
<td>6</td>
</tr>
<tr>
<td>False positive</td>
<td>0</td>
<td>0</td>
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<tr>
<td>False negative</td>
<td>0</td>
<td>2</td>
</tr>
</tbody>
</table>

**Table 2 -** Presence of bone and cartilage using sonographic technique for the assessment in a group of children aged 9 to 16 years.
and diagnostic accuracy were 100% for the sesamoid bone (Table 3). The capping phenomenon was not detectable by sonographic evaluation in any of the cases.

The presence of the fertile cartilage of the distal phalanx of the third finger was correctly identified by the sonogram in 17 of 19 cases (Fig. 3). Children where closure of the epiphysis and diaphysis had occurred and where no cartilage was present were correctly diagnosed by the sonogram in six out of six cases (Table 2). Thus, with regard to detecting the presence of cartilage in the distal phalanx of the third finger, the sonogram had 89% sensitivity and 100% specificity. Its diagnostic accuracy was 92% (Table 3).

The presence of epiphysial growth cartilage in the radius was detected in 20 out of 21 children (Fig. 4). Complete closure between epiphysis and diaphysis, and therefore the absence of cartilage, was accurately diagnosed by the sonogram in four out of four cases (Table 2). Thus, when evaluating the presence of growth cartilage in the radius, the sonogram had a sensitivity of 95% and a specificity of 100%. Its diagnostic accuracy was 96% (Table 3).

**TABLE 3** - Statistical analysis of diagnostic accuracy of sonographic examination based on data from radiographic examination.

<table>
<thead>
<tr>
<th></th>
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<th>Cartilage in distal phalanx of third finger</th>
<th>Cartilage in radial epiphysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensitivity</td>
<td>100%</td>
<td>89%</td>
<td>95%</td>
</tr>
<tr>
<td>Specificity</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>Diagnostic Accuracy</td>
<td>100%</td>
<td>92%</td>
<td>96%</td>
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**Discussion**

Our results compare well with those obtained by Garattini et al. [1998] in their study on hand and wrist sonograms. They showed no significant difference between radiographs and sonographs in the detection of sesamoid bones of the thumb.

A significant difference was found between the two techniques, on the other hand, when detecting...
the cartilage of the distal phalanx of the third finger, primarily due to a reduced accuracy of the sonogram in detecting its profile.

Radiographs have been the procedure of choice for the evaluation of skeletal age in child patients for many years and this technique has been standardised by many authors. With the use of reference templates, the hand and wrist radiograph can be easily and accurately read and interpreted by different operators. At present, radiographs cost less and are more readily available to the patient than sonograms.

However, the sonogram is a harmless, non-invasive, quick and easy to use technique that has the advantage of multiplanar scans [Jaworski et al., 1995; Ferrara and Marcelis, 1997]. Its disadvantage, however, is that it does not allow the visualisation of structures underneath highly reflective and/or absorbent formations, nor does it allow an overall view of the area being examined. In addition, its success depends on the reliability of the operator [Read et al., 1996]. As the sonographic examination technique has not yet been standardised, the operator variability plays a determinant role in the accurate evaluation of anatomic structures [Wagner et al., 1995; Castriota et al., 1998].

Despite its limitations, the sonographic technique showed 92 to 100% diagnostic accuracy compared with radiographic examination in the present study. Therefore, with the techniques used today, a sonographic examination cannot substitute for a radiographic examination of the hand and wrist for the assessment of skeletal age, though it may prove useful as an adjunct to the radiographic evaluation. A sonographic examination could be an alternative to the radiographic examination when monitoring short-term osseous modifications during growth. We strongly feel that in the future, with enhanced sonographic techniques, the sonographic exam may be the method of choice for the evaluation of hand and wrist bones in the assessment of skeletal age in child patients.

Conclusion

Our results show that the sonogram can detect the presence of the sesamoid bone up to the initial appearance of its ossification nucleus. Instead, the hypoechoic bands of the phalanx cartilage and of the radius cartilage could not be detected by sonogram during the terminal phase of growth, just before complete closure of the epiphysis. The capping phenomenon, as well, could not be detected by the sonogram.

References


