Comparison of Valuation Techniques for Bone Age Assessment

N. Olarte L, A. Rubiano F, A. Mejía F.

***Abstract*—**This comparison of valuation techniques for bone age assessment is a work carried out by the Telemedicine Research Group of the Military University - TIGUM, as a preliminary to the Design and development a treatment system of hand and wrist radiological images for children aged 0-6 years to bone age assessment . In this paper the techniques mentioned for decades have been the most widely used and the statistically significant.

Althought, initially with the current project, it wants to work with children who have limit age, this comparison and evaluation techniques work will help in the future to expand the study subject in the system to bone age assessment, implementing more techniques, tools and deeper analysis to accomplish this purpose.

***Keywords*—**Atlas, Bone Age Assessment, Hand and Wrist Radiograph, Image Processing

I. Introduction

ACHIEVE bone age assessment, is an issue that greatly contributes the medicine area to help in determining effective and accurate diagnostic for the growth - related disorders detection.

But, by the time, have been implemented different algorithms applied to image processing, which has contributed to design of complete computational tools in order to reduce time and errors toward the prompt treatment by specialists, focused on this type of abnormalities.

Although, actually not only this assessment is used of disorders growth, has also been used heavily as a support tool in the forensic medicine field for the identification of chronological age.

This comparison of valuation techniques intended to evaluate the methods used by expert radiologists, and for technical professionals also, who have developed computer-aided tools to help automate this estimate.

Although, the bone age estimate tools have been developed, from the engineering point of view has generated contributions to areas such as software development and image processing, its implementation has brought great benefits to areas such as sports medicine and chronological age determination in forensic medicine. The following are the main arguments in these two areas:

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From this side, some sports practice, demands certain physical conditions, such as predominant height, weight and strength to excel, as is the basketball case, where it is necessary to evaluate the athlete from an early age the degree of bone maturation respect to their chronological age, which would greatly promote their performance and athletic success. But there are other sports where physical conditions prevailing, these are not necessary as the case of gymnastics, where weight and height scarce (delayed maturation) are ideal for excellent results.

This influence of bone maturation degree varies by gender, because several men athletes reflect advances in bone age relative to chronological age, as opposed to women athletes, where it is frequent delays bone maturation compared to their chronological age [1].

The sort of sport performed also influences, as a low intensity routine stimulates bone length growth, but high intensity training affects the inhibition of growth [2]-[3].

On the other hand, because of the armed conflict in Colombia there has been a growing demand of bodies in mass graves found, which show a high decomposition degree which does not easily identify their chronological age. This added to the bodies found are from population with variety of characteristics such as gender, race and height, which do not allow carrying out a proper interpretation of the findings from forensic techniques usually employed.

When it is not possible to identify the bodies through of dentition examination, are turning to other techniques, such as obtaining anthropometric measurements, inspection for sexual maturity sings, cervical region radiographic examination and also the left radiographic exam implementation [4].

The latter includes a carpal study to help predict the bodies chronological age, but from this review raises several interest issues: What really is measured parameter obtaining bone age, which method of results interpretation from several would be the most appropriate and finally how to interpret these results, since its reliability varies from one type to another population by their morphological characteristics [4].

Therefore, in this paper will show comparisons of the most important techniques carried out for decades for bone age assessment, organized in chronological way with their advantages and disadvantages.

Initially explains the hand and wrist bone anatomy, and then contemplates the bone maturation concept and its indicators, later the most significant valuation methods and finally the author´s conclusions.

II. Hand and Wrist Bone Anatomy

For the assessment of bone age is necessary to know the anatomy of the hand and wrist, which comprises the following three areas: the wrist, middle, and five fingers. Its skeleton is divided into carpal metacarpal and phalange, for a total of 27 components, as shown in the following Fig. 1.

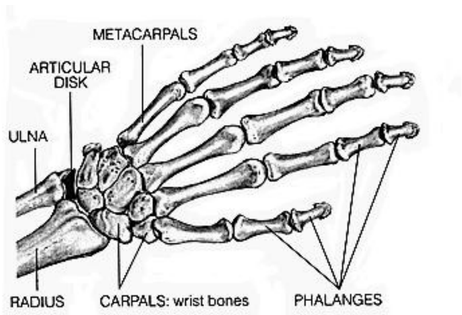

Fig. 1 Hand and wrist bones [5]

Each finger has three phalanges except the thumb which has only two defined in order to more extreme internal as distal phalanx, middle phalanx and proximal phalanx.

The metacarpus consists of five metacarpals, one for each finger, which join the carpus to the phalanges, distinguishing itself as the first metacarpal of the thumb and the fifth, the little finger.

The carpus is divided into 8 bones, which are seen in the following Fig. 2. All components of the carpus are part of the wrist which joins the radius and ulna belonging to the forearm.

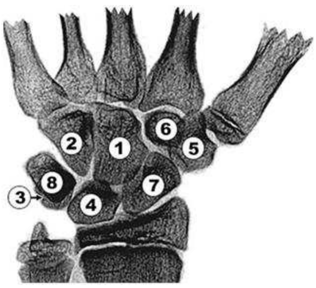

Fig. 2 Depiction of the order of appearance of the individual carpal bones: Capitate (1), Hamate (2), Triquetral (3), Lunate (4), Trapezium (5), Trapezoid (6), Navicular or Scaphoid (7) and Pisiform (8). [6]

III. Bone Maturation

This term, widely used in medicine, corresponds to a measure of development that includes size, shape and degree of mineralization of bone, approaching a defined contour growing to full maturity.

But for this evaluation is necessary to know the different processes of bone development, as changes occur in the growth plate cartilage while merging the epiphysis and diaphysis, recognizing changes in the manner set radiographs moving towards maturity the individual.

Longitudinal growth in the long bones of the extremities occurs through the process of endochondral ossification. In contrast, the width of the bones increases by development of skeletal tissue directly from fibrous membrane.

Bone age assessment is based on an analysis of ossification centers in the carpal bones and epiphyses of tubular bones including distal, middle, and proximal phalanges as well as radius and ulna. Epiphyses usually ossify after birth. With increasing age, the bony penetration advances from the initial focus Fig. 3(a) in all directions Fig. 3(b). Penetration continues until the edges of metaphyses are reached Fig. 3(c). The strip between the shaft and the ossification center diminishes progressively Fig. 3(d) in thickness until it disappears completely at the completion of growth Fig. 3(e), when the epiphysis and metaphysis fuse into one adult bone [7].

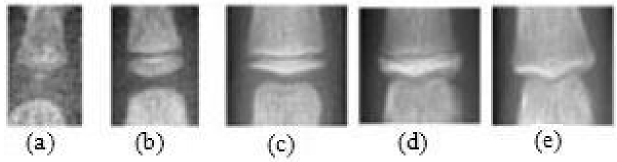

Fig. 3 Ossification centers at different stage of development [7].

To valuate skeletal maturity, is necessary to evaluate which bones in the hand and wrist are the most suitable indicators during the different phases of development. In the majority of healthy children, there is an established sequence of ossification for the carpal (Fig. 2), metacarpal and phalange bones, which is remarkably constant and the same for both sexes [6].

After birth, the epiphyses gradually ossify in a largely predictable order, as shown in Fig. 4, and, at skeletal maturity, fuse with the main body of the bone.

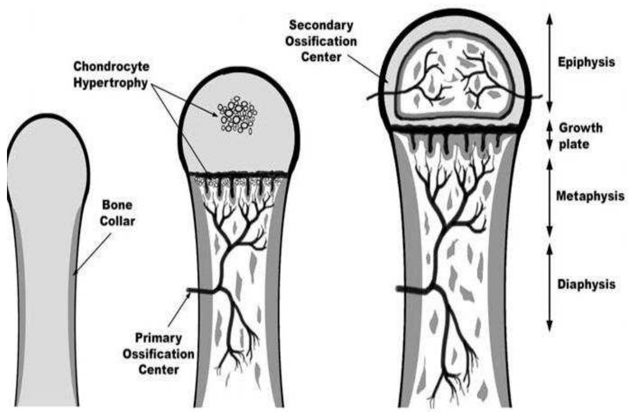

Fig. 4 Schematic representation of endochondral bone formation. Skeletalmaturity is mainly assessed by the degree of development and ossification of the secondary ossification centers in the epiphysis [6]

Comparing the degree of maturation of the epiphyses to normal age-related standards forms the basis for the assessment of skeletal maturity, the measure of which is commonly called “bone age” or “skeletal age”. It is not clear which factors determine a normal maturational pattern, but it is certain that genetics, environmental factors, and hormones, such as thyroxin, growth hormone, and sex steroids, play important roles. Studies in patients with mutations of the gene for the estrogen receptor or for aromatize enzyme have demonstrated that it is estrogen that is primarily responsible for ultimate epiphysis fusion, although it seems unlikely that estrogen alone is responsible for all skeletal maturation [8].

IV. Bone Age Assessment methods

For years, the left hand and wrist were the regions most suitable for assessing bone age, as these areas have ossification centers that provide a wealth of information regarding the determination of bone maturity, also separate organs are far from that may be damaged by radiation.

But you must take into account some observations that influence the determination of bone age is a crucial women's skeleton ossifies or mature first for men and also, on the other hand, some parameters of ossification are inherited.

For this reason, for most techniques, using a carpal radiographs (see Fig. 5) Interpreting many bone´s development and growing factors.

Fig. 5 Hand and Bone Radiograph [9]

Over time, various techniques have been implemented to interpret the various indicators of bone maturation that help in determining their age, will be described more conventional techniques

A. Greulich and Pyle

It has been the method used by radiologists in time for its simplicity, since it is a qualitative graphical method, which compares the hand and wrist radiograph with the standards of Atlas, in which there is a varied collection of x-men and women that allows a statistical analysis for assessing the degree of variation in size as compared to a normal radiograph.

The x-ray study compared with adjacent standards in the atlas, the anterior and posterior close to chronological age, were selected from more similarity then has to conduct a detailed study of individual bones and epiphyses that are visible from end to end, in from the radius and ulna, carpal bones then later the metacarpals and phalanges finally.

However, although it has been the most used method, has been the most accurate for its high degree of subjectivity, as well in practice have considerable morphological variations in different individuals to study, and its origin, this method collected images of middle-class U.S. population - high, normal white and, with time intervals of very large X-ray pattern. Besides this method´s evaluation by several observers sometimes throws different criteria.

B. Sauvegrain and Risser

Although not the most used method in the method Sauvegrain unlike Greulich and Pyle, elbow radiographs are used for a population study of children between 11 and 15 and girls with an age range between 9 and 13.

Extending the age of the study population, there is Risser's method, which comprises a range for men between 15 and 18 and women between 13 and 16 years, analyzing radiographs of the hip, but has one drawback to radiate this region both men and women, because of its proximity to the sexual organs.

C. Tanner Whitehouse

This method is numeric or punctuation, because every bone in his hand or wrist are classified up to 9 states which are assigned a score, the first method was named TW1 and was developed in 1962. But he had some problems because he had big jumps scoring in the later stages of the carpus, having difficulty to recognize them.

The second method developed in 1972, called TW2, assigning to each center of ossification of the carpus, distal epiphysis of the ulna, radius, phalanges and metacarpals 1, 3 and 5 for a total of 20 bones, a score.

The Maturation of Each bone has to be Evaluated by Classifying the bone as Belonging to one of eight (nine for the radius) classes, Usually Labeled with letters A to I, as shown in Fig. 6, which shows the Indicators of maturity sequence of the hamate. In a second phase, the maturity indicator of each bone is converted Into a Corresponding numerical factor by Means Suitable correspondence (look-up) tables. These scores Have Been Evaluated based on criteria optimality-through Statistical Analysis of the Maturation process. The sum of all the bone scores is used as a pointer in another look-up table Which Gives the skeletal age. This estimate depends end to a different degree on all the selected bones of the hand [8]

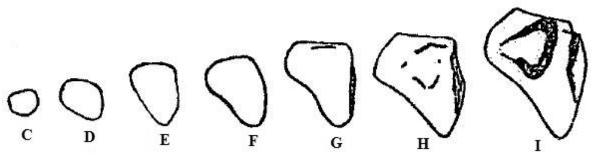

Fig. 6 Sequence of maturity indicators of the Hamate [10]

This method compared to the Greulich and Pyle, doesn't have high error indicators, about the same reading by several observers, also is more sophisticated in its technical application, but depends to the correct hand position on the radiograph for the resulting optimal interpretation of the data.

D. Computer Assisted Techniques for Bone Age Assessment Determinations

These techniques arise from the need for time optimizer, as the bone age estimation by conventional methods depends more on the experience of the radiologist, but keep in mind that to use them, are no longer used analog radiographs but digital, which features key that Automatically extract of hand.

Some of these techniques and edge detection using fuzzy logic operators used to improve contrast between pixels in order to isolate the soft tissues of the bone tissue [11].

But by the year 1987, to take good quality images, since passing the analog to digital radiographs were lost qualities, techniques and segmentation processing [12], although two after segmentation is achieved automatically phalanges, achieving measure four parameters: perimeter, area and length of major and minor axes [13].

During the early 90's, techniques are implemented to smooth images by means of filters, techniques used to extract edges and further develop algorithms to identify regions of interest phalange (PROI) [14]. The dividing is distal phalanges, medial and proximal pulling the length of each of these. But it was also necessary to include the carpal region (CROI), are used for this edge detection techniques to differentiate soft tissue of the bone [15], detection of this region was performed automatically after the umbralizada image is then extracted each of the carpal bones and is individually evaluated by expanding the feature extraction to the whole hand, excluding the ends of radius and ulna [16]. Additional time was applied during the TW2 method to identify measures of each bone of the hand [10].

During the years 2000 to 2010, implemented the first digital hand atlas and web systems for computer-aided diagnosis for bone age assessment [17], algorithms were also used to define regions of interest between the epiphysis and metaphysis of each of the fingers [7], neural networks, fuzzy logic models and active contours for each of the bones [18]. Techniques were implemented to remove the background of the radiographs, drawing only the outline of the hand [19]. We have also developed methods to automatically detect bone age from internet implementing common techniques such as Greulich and Pyle and TW2 both men and women [20].

V. Conclusion

It should take into account that the bone age concept is a clinical experience term evaluated for the maturity person assessing, but their predictions in recent decades have widely helped not only to estimate the growth disorders, but also had influence to medicine sports and forensic sciences, determining in these cases if the bone age state assessed corresponds to the chronological age person assessed.

However should be considered some significative differences will appreciate about this developmental stage in many populations, as it is certainty not known the influencing factors to measure this parameter, sometimes they may be environmental factors or perhaps pathological.

Although currently implemented developments focus on the carpal study, in the forensic field, the bone age assessing techniques are considered more stable than dental evaluation techniques, to get chronological body age estimation more accurately, especially when they are found in the adolescence stage.

However, the Greulich and Pyle and TW2 methods have had great significance during the past three decades, but althought the first one be qualitative and the second one be numeric, both were designed under middle- high class caucasians parameters, currently taking certain population don`t have these characteristics to develop their own specific tables and atlas.

On the other hand, there are automated techniques focused on image processing, but, although algorithms are implemented, choose the region of interest (ROI) is an analysis that defines the difficulty processing of this area, directly affecting the results obtained, well depending on the implement model success.

Although each method has its advantages and disadvantages, the need to improve software systems remains with the radiologists collaboration to optimize the bone age assessment tools, because are the expert who by their personal experience, decide which method is most useful for the interpretation of these data.

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