Biology of Dentofacial Growth and Development: Updating Standards using Digital Imaging Technologies

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Abstract: - Dentofacial growth and development is a complex phenomenon with great impact in the evaluation and treatment of the child. In order to understand individual growth and to elaborate precise diagnosis we need to develop reference values for the present population. For this we had to perform cross-sectional and mixed longitudinal studies on large samples of population over a period of three years. The investigated standards were: dental age, eruption pattern of permanent teeth, odontometric data and prediction tables, dental arch development indices, facial dimensions and proportions and cephalometric measurements. This paper will present and evaluate the principle digital imaging technologies used for updating standards: digital photography, digital models and digital radiography. For analyzing of the digital data we used dedicated software. In conclusion actual computer science and modern imaging technologies facilitates the understanding and characterization of the dentofacial growth and creation of databases for educational and research purposes.

Key-Words: - dentofacial growth and development, standards, dental age, tooth eruption, standardized digital radiography, sequential intraoral photography, digital models, standardized digital photography, anthropometry

1 Introduction
Since dentists and orthodontists are heavily involved in the development of not just the dentition but the entire dentofacial complex, a conscientious practitioner may be able to manipulate facial growth for the benefit of the patient [1].

If we think on orthodontic treatment, we conclude that during this therapy we guide the dentofacial growth [2].

Growth and development of the face is a complex phenomenon, an interrelation between genetics and environment, a tremendous transformation from childhood to adulthood, a process that continues throughout life (Fig.1).

Fig.1 Facial changes on successive photographs taken at 8, 10, 12 and 14 years

That is why we want to know more about biology of growth, the rules, mechanisms and standards of growth and to be able to analyze growth and development of each individual patient.

In order to understand growth and to have up-to-date standard values for evaluation of dentofacial growth and development we have to conduct large surveys. According to literature findings, the majority of standards have a validity of about twenty years. Considering this, there is a permanent demand for studies aiming to develop reference values on present population [3].

Many recent studies on representative samples of population prove the efforts of different countries to update growth standards for each population [3].

Growth studies are of three basic types: cross-sectional, longitudinal and mixed longitudinal. Cross-sectional studies provide the best data for establishing national standards for growth and for comparing growth in different populations. A random or representative sample of 1000 boys and 1000 girls at each age is needed for construction of national standards. Longitudinal studies involve the examination of a group of children repeatedly over a long period during active growth. This method produces the most valuable data for the study of growth rates and the variability of individual growth. Mixed longitudinal studies are a combination of the cross-sectional and longitudinal types. [4]

Nowadays, digital imaging technologies become more and more essential in orthodontic diagnosis and
treatment planning. This is motivated by the high information content of such methods and new possibilities to optimize orthodontic treatment based on that [5].

Orthodontic diagnosis is based on dentofacial growth and development analysis, as well.

2 Problem Formulation

In order to perform such extended surveys and to analyze growth and development of each individual patient it is very important to have those digital imaging technologies that give us the possibility to acquire, save and analyze, control and review a lot of data.

Each growth study requires a lot of precise and organized work and a good management of the acquired data. There is a great demand of having standardized techniques when we do growth and development research.

Those requirements should be facilitated and improved and better results of such studies obtained, when using the modern imaging technologies.

The objective of this study was to evaluate the different applications of computers and digital technologies in dentofacial growth and development surveys and to evaluate the benefits we have when we use this methods comparing to classical methods.

The previously mentioned methods were used for dental age assessment, the determining of timing and sequence of eruption of permanent teeth, odontometric measurements, updating prediction tables and dental arch development indices, photographic facial measurements and comparing with anthropometric ones, cephalometric measurements in order to determine the cephalometric standards on lateral cephalograms.

3 Problem Solution

In order to update some dentofacial growth and development regional standards on Romanian population, we choose to investigate dental age, eruption of permanent teeth, the dimensions of human teeth, parameters that characterize dentofacial arch development and dimensional changes of the face that occur during growth. In order to reach our goals in a short period of time we did mixed longitudinal and cross-sectional studies on children aged between 3 and 16 years. They were organized in subgroups, with different inclusion criteria and age ranges for each study (Fig.2).

The children belong to three different schools, one nursery school or they were patients in our Clinic. On school children we used only noninvasive techniques: clinical assessment, intra- and extra- oral photography, anthropometry and dental impressions. From our patients that matched the inclusion criteria we added some radiographic recordings.

2.1 Dental age assessment

Among other indicators of physiological age, dental age seems to correlate well with chronological age, but not necessarily with skeletal age [6].

For dental doctors this correlations allow an overall summary of dental development and can be used as a basis for further therapeutic decisions.

Such knowledge as dental age can be useful in taking the decision about extracting primary teeth and to decide on timing of the orthodontic treatment. The degree of calcification and the stages of the teeth gives the clinician information about the time and sequence of eruption and early indication about abnormal sequences[7].

Paediatricians are interested to know if the dental maturity of a child with certain disease is delayed or advanced. The correlation between dental and chronological age is also useful in forensic dentistry to estimate the age or to identify the child[6].

In order to investigate the regional characteristics of the dental eruption in the actual population we examined 390 panoramic radiographs of patients aged 4 to 16 using the method of Demirjian.

Patients with agenesis of one or more teeth, distinctive retardation in dental development (except of third molars) or different systemic diseases were not included[8].

Each tooth included has an individual development stage (Fig.3, Fig.4) and then a corresponding score, which is gender dependent. We calculated for each patient a score sum depending on the development stage of the tooth buds from the left mandible quadrant (except the wisdom tooth).
The parameters birth date, date of radiograph, gender and developmental stages of the teeth and the score tables from Demirjian et al. were used to calculate the mean values for score sum and chronological age (Fig. 5). The values of the first 7 teeth of the left mandible are added. If one tooth does not exist, the corresponding tooth on the right mandible is rated.

These methods and clinical norms are recommended by Thomas Rakosi and are used by OnyxCeph™ software, developed by the Firma Image Instruments GmbH, Germany (Fig.6) [5, 9].

All the determined data where included in a large database in order to be analyzed with statistical methods (Fig.7).

As a result of correlation of the score sum and the chronological age we developed conversion tables for the investigated population that differ from that proposed by Demirjian, recommended by Rakosi and used by OnyxCeph™[8].

Digital radiographs have a lot of advantages: the irradiation is reduced with 80% when comparing with a classic one, the clarity of the image is much improved (the clarity is very important when we want to distinguish between two proximal stages, for example when we want to decide if the apex is closed-stage H or the apex is not closed-G) and less artifacts. When we do retrospective cross-sectional studies we have to use conventional radiographs, to scan them with special scanners, to take picture of them or to evaluate them on a negatoscop. When we choose the last possibility, we can not digitize our radiographs and we can not benefit of the advantages offered by OnyxCeph™ or similar software.

Except the conversion tables, that we had to update for our population with OnyxCeph™ we can save, review and control the stages previously given each time we need without the need of any other elements, except our computer. If there are often or/and big differences between the chronological age and the dental age calculated directly with OnyxCeph™ and we respected the inclusion criteria for normal population, we develop new conversion tables for the investigated population.

2.2 Eruption of permanent teeth

The development process, in which primary teeth are exchanged for permanent teeth, is a physiological phenomenon having characteristics not seen in any other body organ. [10]
Adequate knowledge of timing and pattern of tooth eruption are important for diagnosis and treatment planning when working with children in pediatric dentistry and orthodontics. It is also useful in the field of surgery and for determination of age in forensic science [11].

Age estimation for humans plays an important role in mass disasters and unaccompanied or asylum-seeking minors in the absence of proper documents. It also contributes to anthropology [12].

Several authors have reported differences in permanent tooth eruption between ethnic groups and genders [11, 12 and 13].

When we take into account the short period of research time that we have, when we investigate such a dynamic, complex and long biological process we come to conclusion that we have to do our research as a cross-sectional survey or we have to investigate the most dynamic periods when doing mixed longitudinal studies. Another possibility is to create a good database; which can be used by future researchers in a longitudinal study.

The mixed dentition period can be theoretically divided in three sub periods: between 6 and 8 years-the eruption of front teeth; between 8 and 10 years-transition period; between 10 and 12 years- the eruption of the teeth that belong to lateral segments [14]. Investigating each period on different sample in a mixed longitudinal study could represent the solution for our research.

Clinical findings are not enough in order to have the possibility to control the assessed data, to verify the inclusion criteria, to have good research proofs and a database for future research.

Sequential photographs, taken each 3 months and sequential digital models taken each 6 months, in the most dynamic sub periods are tools needed to accompany clinical findings in each eruption research (Fig.8).

![Fig.8 Sequential photographs taken at one year interval](image)

Although the most accurate method for studying eruption order (and positions) of permanent teeth is to trace the dental history of the same individual, many researchers, in consideration of the many years and the various difficulties involved in this method, have opted to study this order in terms of average eruption times (average age at time or eruption).[10]

We determined the mean age of eruption of each tooth and then the eruption sequence by doing a cross-sectional study on 500 children, aged between 5 and 14 years. We made a clinical assessment and a set of 5 intraoral photographs for each child. In order to have better results of sequence of eruption we did a mixed longitudinal study on smaller groups aged between 6 and 8 years and 10 and 12 years. We took intraoral photographs every 6 months and we made a digital model once a year.

### 2.3 Odontometric measurements, prediction tables and dental arch development indices

The introduction of digital models has provided the orthodontist with a viable alternative to plaster models with the added advantages of electronic storage of data, minimal storage space required, simple and accurate cataloguing and a rapid transmission of records for consultation [15].

We can use these benefits when we perform our surveys, in order to determine the dimensional mean values and standard deviations for primary and permanent teeth, elaboration of prediction equations and tables [16, 17] for Romanian population, (useful in the mixed dentition space analysis) or tooth size discrepancies among Romanian children [18]. Cross-sectional dates are enough in order to elaborate these studies. For determining the variation that occurs in dental arches during development we should have longitudinal dates acquired during long periods of time, which requires a digital database that provides a safe storage.

We did a retrospective analysis on 210 plaster models of 97 males and 113 females, between 12 and 23 years of age, with fully erupted canines and premolars. All teeth were in good clinical condition. We scanned the models using a three-dimensional scanner (Activity 101, Firma Smart Optics Sensortechnik GmbH, Germany).

It was verified before that they are no major differences between the measurements carried on digital models and that done with a digital caliper on plaster models [19].

In our study each tooth on digital model was measured, using OnyxCeph™ software (Fig. 9).

The predicted widths of the canines and premolars in both arches were compared with the actual measured widths. Statistical analysis was performed. We reached the conclusion that Tanaka-Johnston analysis and the prediction tables have not enough predictive accuracy for the Romanian population. Significant sexual dimorphism was found in tooth sizes. New probability tables and equations were formulated.
Fig. 9 Measurements on 3D Models were done with OnyxCeph® software

2.4 Facial measurements

Facial changes as a result of growth can be demonstrated by comparing photographs taken at different stages.

The aims of our study were: the development of standards for facial dimensions at 4 years old children [20] and to determine the dimensional changes that occurs between 4 and 6 years; development of facial standards for girls aged 11 and boys aged 13 and the dimensional changes that occur during the peak of adolescent growth spurt.

There are three methods used for facial growth assessment, from which only two are noninvasive: anthropometry and standardized facial photography [21].

Anthropometry is three-dimensional and soft-tissues are included in the evaluation, but it is time consuming and we have not the possibility to control later the acquired data (Fig. 10) [22].

Fig. 10 Anthropometric measurements of the face

Digital facial photography is bi-dimensional, less-time consuming, can be reevaluated later each time it is needed.

In order to have precise photographic measurements the photographic technique has to be standardized.

In our study we used a digital camera (Nikon D80) and dedicated software for analyze. Frontal and lateral photographs were taken by the same examiner, in natural head position. The distance to the subject and the focal length of the camera was standardized [23, 24]. (Fig. 11)

Fig. 11 Standardized photographic technique

We used a cartoon, where we draw two points at 5 cm distance from each other. We place the cartoon parallel to the wall (in the plane of the check, for frontal view photographs and in the midline plane, for lateral photographs). We also used the same cartoon for placing the head so that the Frankfurt horizontal plane is parallel to the floor (Fig. 12).

Fig. 12 Technique used for lateral (left) and frontal (right) view photographs

We could measure different facial diameters and proportions between them and we could do different analysis as Symmetry analysis and Profile analysis.

Comparing photographic measurements using this technique with anthropometric measurements of the same face we obtained similar values. Our results encouraged us to use the digital photographic standardized technique when we want to determine the facial growth standards, because it is complex, fast and easy to be reproduced as many times it is needed (Fig. 13, Fig. 14).

Fig. 13 Frontal photograph analyzed with dedicated software

Fig. 14 Lateral photograph analyzed with OnyxCeph®

2.5 Cephalometric measurements on lateral cephalograms

In all this digital software the standard values are from international literature and studies and does not always correspond with the actual norms of our patients. Studies of our actual population are very important and we are working on this (Fig. 15).
Fig. 15 Cephalometric analyze of a digital radiography with the same software

4 Conclusion

Actual computer science and modern imaging technologies facilitates the understanding and characterization of such a complex biologic transformation as the dentofacial growth is and also helps a lot in creation of databases for educational and research purposes.

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