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GUEST EDITORIAL

Soft-tissue 3D Facial Imaging in Children and Adolescents: Towards the Definition of New Reference Standards

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In the last decades, head and face imaging has shifted from two-dimensional (2D) representations (conventional radiography, photography) to three-dimensional (3D) techniques that can better depict the complex morphology of this part of the body, since they can provide a large number of additional anthropometric information [1-3]. 3D imaging systems can be divided into volumetric (computed tomography, cone beam computed tomography, magnetic resonance imaging) and optical surface instruments (laser scanning, moiré techniques, stereophotogrammetry, patterned light techniques) [4]. These last are safe and not invasive, and provide a 3D representation of the external (cutaneous) facial surface.

Among all instruments, stereophotogrammetry is becoming the most diffused and used for both adults and children. Stereophotogrammetry is fast (typical scan time 2 ms), and it provides 3D photographs coupling a 3D mesh of the analyzed surface with a color facial image (texture). The technique takes photographs of the face from at least two different positions with two or more cameras (or set of cameras) at the same time. Using a previous calibration of the instrument, these coordinated photographs are combined to form a computerized stereoscopic reconstruction of the face [3,4]. Stereophotogrammetric systems have proven to be repeatable and able to provide accurate measurements [4,5].

Alongside with stereophotogrammetry, some laboratories and research groups are using laser scanners. The device illuminates the object with a low-intensity laser, and digital cameras capture the images. During data acquisition, either the laser light or the face rotate to sample the entire surface; triangulation geometry provides the depth information [6]. A multicentric study showed that laser scanning and stereophotogrammetric acquisitions can provide superimposable data, that can be efficiently shared among laboratories [7].

3D optical surface assessments can be of great value in clinical applications, at all ages of life, but especially for children where the concerns about radioprotection are maximized [3].

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A PubMed search using the key-words "3D, face, human" retrieved 1628 full text papers published between 1965 and 2017; if "babies or children or child or adolescent" were added as key-words, the retrieved papers were 399 (https://www.ncbi.nlm.nih.gov/pubmed/, accessed on November, 4th 2017). Interestingly, the majority of these papers were published in the last 7 years (59% and 67%, respectively), thus confirming a growing interest in this topic, with an increment specifically higher for people in their first decades of life.

The fields of application of 3D facial imaging are diverse, ranging from those more frequently encountered by dentists to more rare disorders that anyway possess specific craniofacial characteristics of dental interest. Examples include the evaluation and treatment planning of children with occlusal abnormalities [8,9], orofacial clefts [10], or cranial deformities [11], as well as the early diagnosis of congenital and genetic disorders (Down's syndrome, ectodermal dysplasia, Glut1 deficiency syndrome, Moebius syndrome, velocardiofacial syndrome) or acquired pathologies like fetal alcohol syndrome that modify facial phenotype [12-18].

The use of new 3D techniques, with a better characterization of the anthropometric facial features, implies that these specific clinical purposes should be accompanied by the definition of appropriate reference values, that may be considered the new Bolton reference standards [19]. The formulation of reference standards requires the collection of cross-sectional (usually) and/or longitudinal (hopefully) data from normal subjects of comparable age, sex and ethnicity [3,20]. Indeed, even for genetic pathologies like Down's syndrome, where the original disorders is mostly the same all over the different ethnical groups may possess specific characteristics with a resulting particular phenotype [14,21]. Therefore, reference values should be collected in healthy people sharing the highest possible number of common factors with the patients.

It is clear that this task is actually very complex, and only a word-wide collaboration can succeed in the goal. There have already been some examples of multicentric data collection, but in most cases this was limited to adults [7,22]. For instance, data provided by Farkas et al. [22] were obtained in 1470 healthy adult subjects (18 to 30 years), equally divided in the two sexes. The largest group was made by European Caucasians, with minor contributions from Middle-East, Asia and Africa; data were compared to literature values for North American whites. Indeed, most of the values were obtained by conventional anthropometry, but the method used in this study could be taken as reference: the late professor Farkas invited colleagues who had published on the topic, defined the measurement protocol and the characteristics of the sample, and collected data. The original information was combined into a general framework of great interest: the paper is the most cited Farkas' one, with 230 citations (retrieved in Scopus https://www-scopus-com.pros.lib.unimi.it:2050/search/form.uri?display=basic, accessed on November, 12th 2017).

As far as children and adolescents are concerned, some research groups are working towards this goal. One initiative is FaceBase (https://www.facebase.org/, accessed on November, 12th 2017), a consortium launched in 2009 and funded by NIDCR (National Institute of Dental and Craniofacial

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Research, USA), where scientists can find data supporting researches about craniofacial development and malformation. Alongside with genetic, molecular and biological data, the database also hosts facial images. Currently, there are photogrammetric scans of more than 700 healthy Caucasian American children from 3 to 12 years of age. The dataset is available to the research community, and it aims to foster and facilitate worldwide cooperation and collaboration. Weinberg et al. [3] recently published the results of an inter-centers collaboration based on FaceBase data repository, with data from 2,454 subjects of both sexes and aged from 3 years onwards. From the same source, Kesterke et al. [20] analyzed 1,555 healthy persons from 3 to 25 years of age.

In Europe, more than 2,500 German children aged 3-6 years were photographed in 3D by Moller et al. [23], while Bugaighis et al. [24] collected data on 80 Caucasian children from the North East of England aged 8–12 years. Forty-five Czech children were longitudinally studied between 12 and 15 years of age by Koudelová et al. [25] using stereophotogrammetry. Welsh children aged 11.8 years on average were analyzed by Kau et al. [6] using a laser scan. In our laboratory we had been collecting 3D data for the quantitative description of soft-tissue facial morphology for more than 25 years, providing reference values for more than 2,000 Italian children from 4 years of age onward [26,27].

Reference values for children belonging to countries and ethnic groups outside Northern America and Europe are actually very scanty. In Asia, Mori et al. [28] scanned in 3D the nasiolabial characteristics of Japanese boys and girls aged 5 to 6 years, while Al-Khatib et al. [29] studied the 3D characteristics of the nose of Malaysian adolescents aged 13 to 17 years. In Africa, Sforza et al. [30,31] published reference values for more than 650 Northern Sudanese people from 4 years of age into young adulthood.

Babies in the age range of 0-6 years have almost been neglected so far. Indeed, collaboration from very young persons (and from their families in some occasions) can be difficult, and the organization of data collection very demanding, even if the actual time necessary for the stereophotogrammetric or laser scans is very reduced. About one hundred Scottish babies aged around 3 months of age were imaged by both White et al. [32] and Hood et al. [33]. Other investigators started data collections at 3 [3,20,23] or 4 years of age [27].

In conclusion, 3D optical, surface imaging is becoming an important instrument for diagnosis, treatment planning and follow up of children, who should not receive ionizing radiations unless strictly necessary. The instruments are fast, safe, and neither painful nor fastidious. Their use for clinical applications should be accompanied by a systematic data collection in healthy young people, spanning from birth to late adolescence into young adulthood. Researchers all over the world should collaborate towards this goal, with the definition of these new facial standards.

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