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Review

A review of the literature on the aging adult skull and face: Implications for forensic science research and applications

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Abstract

This paper is a summary of findings of adult age-related craniofacial morphological changes. Our aims are two-fold: (1) through a review of the literature we address the factors influencing craniofacial aging, and (2) the general ways in which a head and face age in adulthood. We present findings on environmental and innate influences on face aging, facial soft tissue age changes, and bony changes in the craniofacial and dentoalveolar skeleton. We then briefly address the relevance of this information to forensic science research and applications, such as the development of computer facial age-progression and face recognition technologies, and contributions to forensic sketch artistry.

Keywords: Craniofacial aging; Craniofacial morphological changes; Adult skull and face age changes; Facial age-progression

Contents

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1. Introduction

Two of the last published broad reviews on the topic of adult craniofacial age-related changes were made over 20 years ago, and discussed studies spanning from the 1860s to the early 1980s [1–2]. Information on craniofacial age-related changes forms the basis for the forensic study or practice of facial reconstruction, adult facial age-progression, and automated face recognition technologies. Here we provide results of an up-to-date survey of published research, with an emphasis on the last 20 or so years, on the topic of craniofacial age-related morphologic changes, noting major contributions since the last broad reviews were made in the early 1980s [1–2]. Next, we synthesize and summarize the key factors influencing how the adult head and face age, as well as the ways in which craniofacial morphology changes from young adulthood through senescence. Finally, we discuss the importance of an interdisciplinary approach to understanding adult craniofacial age-related changes as it relates to adult facial age-progression methods, 3D computer modeling of faces, and automated face recognition technologies for use in forensic science.

2. Material studied

The published literature on adult head and face aging is diverse, spanning topics related to anthropology and biology, medicine and pathology, and computer and forensic science. Our aim is to integrate key findings from this broad review inasmuch as the studies reviewed were relatively narrow in focus. It is imperative to understand that patterns, rates, and or characteristics of aging may be different due to culture and lifestyle (environment, gender) and biology (sex, ancestry or genetics, trauma and disease), as well as idiosyncratic features, such as frequency and extent of facial expressions. The way in which patterns, rates and or characteristics of aging vary among people at any given age, or change over time in any one person, are not completely understood. Below we present our methodology and examples of the diversity of the literature reviewed. Later, we discuss further the results of our review that are particularly relevant to forensic science.

Our research questions for this study were: What causes or influences human adult face aging, and what are the craniofacial morphological changes that take place as the human adult ages? To study these questions, we conducted a review of the literature over roughly the past 20 years. The literature review methodology employed in this study was modeled after the procedure set forth in the *Cochrane Handbook for Systematic Reviews of Interventions* [3].

We (1) articulated our research questions (above), and (2) selected key words and phrases for our literature searches (examples are provided below). (3) We focused on ScienceDirect as our electronic bibliographic database since it encompasses international forensic science, medical, and anthropological literature across a wide time range, and is a major database used worldwide with links to abstracts. (4) The relevancy of the literature found was determined from information from the abstracts. For all works deemed relevant, we (5) obtained full text articles and or books.

While some of our key words and phrases resulted in locating pertinent literature, many irrelevant works were also identified in the searches. This led to either a modification of key words and phrases or dropping the key words and phrases altogether in favor of alternative key words and phrases. Thus, numerous phases of literature searches resulted. Examples of the array of search words and phrases included: craniofacial growth, human adult face aging, face aging, adult face age changes, age-related face changes, craniofacial morphological change, craniofacial age change, craniofacial adult change, craniofacial adult growth, age-related craniofacial change, skull age change, cephalometric age-related change, cephalometric age, cephalometric dental, cranial base, dentoalveolar age change, and cranial thickness.

The literature on craniofacial aging is robust to aging in terms of growth and development, and maturation from infancy and childhood up to adulthood, for medical and dental applications [4–19]. Aging of specific features of the head and soft tissues of the face has also been studied with regard to facial plastic and reconstructive surgery, e.g. [20–25]. Facial wrinkling as a result of environmental perturbations is another aspect of aging well documented in the literature, e.g. [26–28]. From an evolutionary perspective, there are comparative studies on craniofacial variation and growth changes among humans and other apes, e.g. [29–30], and secular changes in modern humans [31]. There is also some population-based information on craniofacial age changes in non-white populations, such as growth in African Americans [32], aging in black Africans [33], and a comparison of skin aging between Chinese and European populations [34].

Further, craniofacial aging and craniofacial anthropometry pertinent to forensic facial reconstruction and identification have become fairly well represented in relatively recent publications [35–45]. Current trends in forensic facial identification studies include attempts to improve facial age-progression techniques [46–48] and methods to quantify aging parameters [49]. Craniofacial aging data are increasingly important where automated face recognition technology and computer 3D modeling of adult faces for use in adult facial age-progression are concerned [50–57]. Earlier efforts, such as the Facial Recognition Technology (or FERET) studies [58–61], attest to the potential benefits of a cross-disciplinary interface between forensic anthropology and computer science with forensic science in general. Indeed, it has been noted that more research involving human facial aging is needed by the forensic anthropology community [62]. Presently, there is a paucity of information on bony changes of the head and face in adulthood in standard popular osteology and forensic anthropology reference texts [63–67]. However, there are numerous published studies addressing various specific areas of morphological change associated with age or aging in adult craniofacial features [1–2,6,15,68–87], and findings from these studies are the focus of this paper.

The results of our review of the literature that are most pertinent to adult craniofacial aging include environmental factors that contribute to adult aging of the face, and naturally occurring size and shape changes of the head and face (i.e., adult age-related hard and soft tissue changes). First, we indicate what is known, to date, to influence aging of the head and face. Second, we present our findings regarding hard tissue age changes, followed by soft tissue age changes. Where applicable, differences due to adult age, sex, and ancestry, or other variables, are addressed. Finally, we address the implications of the above information to forensic science.

3. Results and discussion

3.1. Factors influencing adult facial aging

The aging adult face is influenced by numerous environmental perturbations such as solar radiation, smoking, drug use, and psychological stress [26–28,41,44]. For example, photoaging (i.e., skin aging due to solar radiation) may expedite or accentuate the process of aging that likely occurs naturally over time [20]. Photoaging is an extrinsic factor of aging, whereas intrinsic (or innate, chronological changes) are age changes occurring naturally over time [20,44]. We describe extrinsic factors affecting aging first, followed by factors influencing innate changes.

3.1.1. Environmental influences

Aside from photoaging which mainly affects the skin and exaggerates normally occurring age changes, general exposure to the elements, such as wind and arid air, can influence facial aging [44]. There is some debate about the effects of smoking on aging faces [41], where smoking has been listed as one factor contributing to aged appearances [44], but where another study found smoking to have little effect upon facial wrinkling [26]. Smoking disrupts the microvasculature of skin, which in turn affects the integrity of elastin and collagen. Dehydration can result in a grayish cast to the complexion. Lines around the mouth, circumoral striae, may become evident. Despite these possible effects, it is thought that photoaging results in more severe wrinkling than smoking [26,44].

Generally, exposure to the elements, drug use, and stress-related decreases in sleep are deemed influential in facial aging [44]. Exposure to the elements alters the color and texture of the skin such that the complexion becomes blotchy, freckled, may have a yellowish tinge, and or may become loose and inelastic or leathery. Blood vessels near the surface of the skin may also seem more pronounced, resulting in a ‘‘spider vein’’ appearance. These features are more evident in lighter-skinned people as photoaging occurs more slowly in darker-skinned people [41,44].

3.1.2. Innate changes

Innate adult facial aging results from: (1) changes in the bony support structure of the face and subsequent changes in musculature, and from (2) gravity and (3) hyperdynamic facial expressions. Other changes related to advancing age include loss of tissue elasticity and facial volume, and alterations in skin texture [87]. Although the manner of aging can be highly unpredictable, there is a *sequence* of changes that appears to adhere to a basic progressive pattern across time. The *rate* of aging, however, varies across adult ages. There is a strong likelihood that certain adult time or age spans yield a greater magnitude of age-related changes than other time or age spans. For example, there may be minimal changes seen from ages 20 to 30 years, while by contrast there may be noticeable changes from ages 40 to 50 years. Attempts have been made to effectively express the sequence or stages of aging [44]. Detailed information on bony and soft tissue changes of the face as a function of age were found [20], with specific reference to the upper lip [1,71,75,78,81,84], nose [1,71,81,84], and ear [1,85,86]. As well, key facial age changes have been studied by adult decade of life, where ‘‘aging’’ is noted to appear in the upper face before the lower face [41].

It has been suggested that differences exist in the rate of soft tissue facial aging by decade of life, and perhaps by sex and ancestry [41,84], but detailed, quantifiable information on rates of change are not known. Indeed, sex differences have been noted in several studies we reviewed, which we will discuss in upcoming sections of this paper. While it is widely accepted that females tend to mature and age faster and or earlier than males, it is not clear if craniofacial sex differences are due to differences in the rate of aging per se, or sexual dimorphism, or shifts in hormonal levels, as suggested by Doual et al. [77], further discussed below. Sex differences in the studies we reviewed are presented where applicable (i.e., where differences were noted and or significant in those studies); however, we did not consider the causes for the sex differences in this study. Aside from the issue of the rate of aging, and sex differences, the *sequence* by which myriad facial features change with age has been observed.

The general sequence of aging is somewhat predictable, with the understanding that the pace, exact timing, and extent of any one aging feature may be unpredictable due to normal human variation. The appearance of facial lines and wrinkling [41], and their appearance in response to loss of muscle, bony changes, and the natural passage of time have been documented [20]. It is noteworthy that soft tissue facial age changes in general are a reflection of underlying bony changes; therefore skeletal or hard tissue changes are discussed first, followed by soft tissue changes.

3.2. Hard tissue facial age changes in adults

Although much of the published literature on age-related morphological changes in the skull is characterized by studies aimed at specific features, there is support for the broad-based assertion that skeletally, the head and face do continue to change throughout adulthood. This change is more a remodeling of bone that is part of the normal aging process. However, bony tissue changes of the head and face do not always lead to predictable patterns of change in the overlying muscles and skin of the head and face [44]. This presents a challenge in facial reconstruction efforts and attempts to develop effective age-progression techniques. Nevertheless, Taylor [41] provides photographs of individuals taken at various adult stages of life, where the most notable soft tissue changes were observed around 50–60 years compared to other decades of the adult lifespan. Further, Doual et al. [77] found from their study of 21–101-year-old females and males that the most profound morphological modifications due to age in the head, face, and neck become evident around 50 years in females and males. Females showed greater changes, and the authors suggest this is due to the effects of menopause. Doual et al. offer no further discussion of how menopause plays a role; and similarly, as aforementioned, this review does not consider the causes of sex differences. However, we report findings of sex differences where noted beyond the sample descriptions.

Other factors that age the skin alone, such as photoaging, occur independently of bone remodeling. Further, recall that environmental factors affecting the aging face may occur independently of, or be exaggerated by, underlying bone remodeling. Remodeling of the bony head and face results in horizontal, vertical, and sagittal shape changes, dentoalveolar changes, as well as face contour changes, discussed next.

3.2.1. Horizontal changes

Craniofacial skeletal changes continue to occur at least until the third decade [84]. Behrents's 1985 [1] review of the literature from roughly 1865 through the early 1980s, shows that bony changes in the head and face continue into the fifth and sixth decades of life. Guagliardo's 1982 [2] literature review corroborates this finding as well. Moreover, the craniofacial skeleton seems to increase in size horizontally during the entire adult lifespan; enlargement was observed longitudinally in females and males from the third through eighth decades of life [69–70]. It appears well understood that craniofacial skeletal change displays no uniformity [69]. Reasons include normal human variation due to sex, ages at which various dimensions were measured, environmental influences, ancestry, and possibly secular change. Sample sizes and methods of analysis may be partially responsible for varying findings.

Cranial horizontal changes refer to shape changes as well as an increase in certain dimensions. Most craniofacial dimensions have been found to change by small increments, ranging from 1.1 mm [1] to 1.35 mm [75] and 1.60 mm [73]. Though seemingly small, the magnitude of change may have an impact on how the soft tissue features of the face are altered as a result of the bony shifts in various dimensions. More generally, cranial dimensions that increase include head circumference, head length, bizygomatic breadth, and head breadth. How much, when, and in what order these changes may occur is not known since sample size differences, populations studied, and statistical methods of analysis varied widely, as seen in the studies discussed by Behrents [1] and Guagliardo [2].

3.2.2. Vertical changes

Anterior face height tends to increase with age [2,71,73,75,81,84]. Forsberg et al. [73] reported that the total anterior (bony) face height in individuals in their study increased by about 1.60 mm, where about 1/5 of the increase occurred in the upper face and 4/5 of the increase occurred in the lower face. Similarly, Bondevik [75] found changes in anterior facial height, mostly in the lower face, in a sample of 22–33-year-old Norwegian females and males [75]. Forsberg et al. [73] also found an increase in mandibular length, as did West and McNamara [81] when they analyzed female and male cephalograms taken at age 15 years, then again when the participants were in their 30s and 40s. Dentoalveolar vertical changes are related to the above, and are discussed after cranial sagittal changes and dentoalveolar sagittal changes, below.

3.2.3. Sagittal changes

Although research findings support shape changes in the craniofacial skeleton throughout adulthood, very aged people actually seem to show a decrease in craniofacial skeletal size, perhaps related in part to alveolar bone remodeling [1]. Doual et al. [77] found highly statistically significant increases in thickness of anterior–posterior measures of cranial bone, but no apparent change in the overall anterior–posterior diameter (i.e., horizontal change) of the calvarium. An increase in cranial thickness, correlated with advancing age, was reported by Behrents's [1] although there is also evidence to the contrary [80,83]. Ross et al. studied cranial thickness in 58 female and 122 male frontal and parietal sections, from US individuals of known age (18–87 years), sex, ancestry, and cause of death. Even though the authors report an overall increase in cranial thickness with age, they indicate that males showed a steady decrease when analyzed separately from females. Specifically, females showed a *steady* increase in cranial thickness up to about age 65 years, at which point there was an *abrupt* increase in cranial thickness associated with pathology—hyperostosis frontalis interna (HFI). That males showed a decrease, and females showed a steady increase (excluding the abrupt increase due to pathology at >65 years), seems to support a general overall pattern of sex differences found in other studies on adult age-related head and face changes, some of which will be addressed under soft tissue age changes. Ross et al.'s results [80] should be read with caution, however, given findings from Lynnerup's study [83] of an autopsied Danish forensic sample.

Lynnerup [83] examined cranial thickness in 64 individuals: 21 females aged 23–84 years and 43 males aged 16–90 years. No statistically significant differences were found in cranial thickness, nor were there any correlations between cranial thickness and sex, age, or height and weight of the individual. It was interesting to note that calculated means for cranial thickness were larger in females (i.e., females had thicker measures), but cranial thickness ranges were wider for males. Lynnerup emphasizes, and we agree from our own review of the literature, that myriad factors account for the variation in research findings, such as sampling bias (e.g. small sample sizes, samples limited to certain historic anatomical collections or homogenous populations), the confounding effects of pathology, methodologies in data collection, and ways in which data are analyzed. Findings that are supported by multiple studies across time may therefore be given greater credibility [83].

3.2.4. Dentoalveolar changes

3.2.4.1. Sagittal changes. Reich and Dannauer [76] found that with increasing age, prognathism tended to increase in degree in the maxilla and mandible in their sample of orthodontically untreated native Saxon individuals ($n = 10{,}047$). Bishara et al. [74] studied facial and dental features in adulthood and noted that clinically significant increases in tooth-size arch length discrepancies occur between ages 25 and 46 years. Tooth-size arch length discrepancy refers to the relationship of the teeth to the maxillary and mandibular dental arches. There was increased crowding of the mandibular arch in females, and of the maxillary and mandibular arches in males. These bony changes affect the positioning of the nose and chin, and result in the lips appearing more retrusive by age 46 years [74].

Taister et al. [44] also addressed the ways in which dentoalveolar changes affect the appearance of the aging face. For example, remodeling in the alveolar bone after tooth loss can cause a variety of facial appearances, such as a concave look to the face, hollow cheeks, and diminished jaws.

3.2.4.2. Vertical changes. Forsberg et al. [73] conducted a longitudinal study documenting craniofacial and dentoalveolar changes in females and males ($n = 30$) from ages 25 to 45 years. Results indicated significant dentoalveolar regression, which suggested an eruptive movement of the teeth. Arman Akgül and Toygar [84] corroborated that there are dental arch decreases in females and males and continued eruption of teeth. Further, Pessa et al. [79] found evidence for maxillary retrusion being a normal feature of aging. Retrusion, a backward displacement, is thought to contribute to the formation of the nasolabial fold—the wrinkle or crease in the skin, diagonal from the base of either side of the nose to the outer edge of the mouth.

Taister et al. [44] suggest that arthritis in the temporomandibular joint, which can cause remodeling and a flattening in the joint, leads to a decrease in the vertical height of the face. These authors cite dental attrition as leading to a decrease in the vertical height of the face. It may be that this finding relates more to abnormal attrition or posterior tooth loss, given that other studies [73,84] showed a continued eruption of teeth, as mentioned above. The continued eruption of teeth may very well compensate for the effects of normal attrition, thereby clarifying a seeming contradiction between decreased versus increased anterior face height. Indeed, the finding that anterior face height increases, mainly in the lower face, is strongly supported in the literature by several studies, e.g. [15,71,75,81,84].

Arman Akgül and Toygar's [84] study emphasized the importance of the cranial base in influencing facial and other cranial regions as individuals grow, develop, and age. They studied cephalometric films and dental casts of 30 individuals (14 females, mean age 22.35 years, and 16 males, mean age 22.19 years) taken between adolescence and young adulthood. They then compared the data from the same individuals about 10 years later, during young to middle adulthood. The authors found that the most significant changes occurred in the vertical dimension rather than the sagittal dimension. The total anterior face height increase was largely attributed to increased height in the lower face, most likely due to the minor continued eruption of the teeth—a finding supported by Forsberg et al. [73] as aforementioned, as well as Sarnäs and Solow [71].

Sarnäs and Solow [71] studied changes in the cranial base in females and males aged 21–26 years and found anterior face height increases about 1.5 mm, where this increase was greater in the lower face compared to the upper face. Continued eruption of the lower incisors was found to be the major factor leading to the greater increase in lower anterior face height when compared to upper face height. Moreover, this finding was corroborated by Hahn von Dorsche et al. [15]. Sarnäs and Solow [71] and Hahn von Dorsche et al.'s [15] findings are in agreement about the major increase in skeletal dimensions occurring in the lower anterior face height during the early 20s for both females and males.

Findings from Bondevik's [75] study on natural growth changes of the cranial base and face yielded some noteworthy findings regarding the cranial base and face. From a series of cephalograms taken of 164 Norwegian females and males – at age 22 years and again at age 33 years – Bondevik found that overall, anterior face height increased (mostly in the lower face, as mentioned earlier), as did mandibular length, both of which were statistically significant for the females in the sample as well as the males. Further, females showed a posterior rotation of the mandible, which was statistically significant. Soft tissue findings are discussed later.

3.2.5. Skeletal and soft-tissue facial contour changes

As the anterior facial skeleton displays greater convexity with age [73,78], the soft tissues of the face seem to become more protuberant [44]. This aspect of aging coincides with growth in the nose and ears, and lengthening of the lips. Table 1 summarizes the above adult bony age-related changes, combined with those for adult soft-tissue age-related changes described below, across the adult age span.

3.3. Facial soft tissue age changes in adults

Below is a synthesis of findings from three publications detailing general soft tissue age changes in adults, decade by decade [20,23–24]. Following this overview, we discuss specific findings of soft tissue age changes noted from key cephalometric studies [71,78,81].

3.4. General soft tissue changes

Generally, normal aging of the facial soft tissues begins in the 20s with fine facial lines appearing horizontally across the forehead, vertical lines emerging between the eyebrows, and faint lines developing around the outer corners of the eyes (i.e., ''crow's feet''). These faint lines continue to deepen in the 30s and beyond. In the 30s, horizontal lines appear at the top of the nose between the eyes, and nasolabial lines begin to form (lines or creases from the outer corners of the base of the nose diagonally down to the sides of the mouth). During the 40s, many soft tissue age changes occur. The inferior orbital groove may develop (a crease below the inner corners of the eyes down diagonally and laterally across the tops of the cheeks), the eyebrows may drop, and the upper eyelid may droop and obscure the upper eyelid crease around the lateral margins. The

Table 1
Adult hard and soft-tissue age-related changes

Approximate age range (years)	Likely bony change	Probable soft tissue or facial appearance effect
20–30	• Slight craniofacial skeletal growth. • Slight anterior (mostly lower) face height increase. • Mandibular length increase.	• Upper eyelid drooping begins. • Eyes appear smaller. • Nasolabial lines begin to form. • Lateral orbital lines begin to form. • Upper lip retrusion begins in females.
30–40	• Dentoalveolar regression suggesting eruptive movement of teeth. • Maxillary retrusion progressing, contributing to nasolabial folds. • Mandibular length increase.	• Circumoral striae begin to form. • Lines begin to form from lateral edges of nose to lateral edges of mouth. • Upper lip thickness decreasing.
40–50	• Craniofacial skeletal remodeling progresses. • Dental alveolar regression and dental eruption progressing. • Maxillary and mandibular dental arch lengths decreasing.	• Facial lines and folds continue to increase in depth. • Nose and chin positioning affected as dental arch lengths decrease. • Most profound morphological changes of the head, face, and neck are evident.
50–60	• Craniofacial remodeling continues. • Cranial thickness likely unchanging. • Alveolar bone remodeling. • Possible dental attrition affecting vertical face height.	• Facial lines and folds continue to increase in depth. • Protuberance of nose and ears due to greater craniofacial convexity.
>60	• Decrease in craniofacial size. • Greater craniofacial convexity (excluding maxilla and mandible). • Possible temporomandibular joint arthritis and joint flattening. • Alveolar bone remodeling continues.	• Protuberance of nose and ears continues. • Concave appearance in cheek hollows due to alveolar bone remodeling. • Diminished jaws.

lower jaw becomes less firm, circumoral striae develop (lines around the mouth), and the lips can thin out. An oromental groove becomes noticeable (horizontal lines at each corner of the mouth, expanding the width of the mouth), as does a mentolabial groove (a horizontal groove below the lower lip and above the chin).

In the 50s, more prominent soft tissue age changes become evident. The groove or crease below the eyes may evolve into a pouch of skin. More tissue may develop on the upper eyelid where drooping further obscures the crease of the upper eyelid. Existing creases, lines, and grooves continue to deepen. The lips become thinner. If tooth loss occurs, the cheeks can appear hollow. A buccomandibular crease can form (a mostly vertical crease at the sides of the cheeks above the lower jaw). There is diminishing jaw firmness. Jowls and a double chin may develop. Wrinkles in the neck can become apparent. In the 60s, the aging features of the previous decades become more pronounced. During this decade, the nose and ears appear longer, the jaw has lost its firmness, and soft tissues of the neck sag. By the 70s and beyond, creases, lines, and grooves are all exaggerated. There is a loss of skin elasticity, and significant skin sagging. Table 1 summarizes the above soft tissue changes along with those hard tissue changes presented in the previous section.

3.5. Specific soft tissue changes

3.5.1. Nose

Sarnäs and Solow's [71] longitudinal cephalometric study examined adult craniofacial change in a Swedish Caucasian sample of 50 females and 101 males for the 5 years from ages 21 to 26 years. Results for the nose were as follows: the length of the nose increased between 0.75 and 1.00 mm in both sexes; the height of the nose increased by about 0.50 mm in both sexes; and there was no statistically significant change in the depth of the nose (i.e., from nasion to subspinale). The nose did, however, move forwards and downwards in both sexes; and the authors state that it can be inferred that this movement occurred in relation to anterior cranial base changes. For example, both nasion and subspinale points showed a slight forward movement relative to anterior cranial base features, which likely led to the nose moving forwards and downwards. Moreover, West and McNamara [81] found that the nose showed a slight downward movement from late adolescence to early adulthood (18 years to 30s,) as well as from early to middle adulthood (30s to 40s).

Bishara et al. [78] convey the changes in soft tissue facial profiles based on analyses of lateral cephalograms from a sample of 15 females and 20 males, originally part of the Iowa Facial Growth Study, begun in 1946. Data were available for these 35 individuals at ages 5, 10, 15, 25, and 45 years. The authors suggest that the increase in overall facial convexity found with age (5–25 years) is due to a greater increase in the prominence of the nose, compared to the rest of the soft tissues, during growth. In middle adulthood (age 45 years), the angle of facial convexity increased either due to a more vertical enlargement in the tip of the nose, or a more forward movement of the chin. Although no studies detailing age-related changes in the nose beyond age 45 years and into senescence were

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identified, anecdotal evidence seems to support that continued shape changes of the nose occur with advancing age.

3.5.2. Lips

Regarding age changes in the lips, Sarnäs and Solow [71] report that in their sample of individuals studied from ages 21 through 26 years, upper lip height increased significantly, by about 0.50 mm in both sexes, whereas lower lip height increased by about 0.20 mm, but was not statistically significant. Lip thickness was reduced by about 0.50 and 0.25 mm in females and males, respectively. For both lips, the distance to the nose–chin line increased by about 0.50 mm. Bishara et al. [78] report that between ages 15 and 25 years, the upper and lower lips became more retruded relative to the esthetic line, with similar trends continuing between ages 25 and 45 years. For females, the greatest change was seen between ages 10 and 15 years, and for males between 15 and 25 years. Arman Akgül and Toygar's [84] findings also support significant upper lip retrusion in females in the 20s. West and McNamara [81] found that for females and males, during the time from early to middle adulthood – from the 30s to the 40s – the lips move downward, flatten, and lengthen. These findings are similar to Behrents's results [1]. That females exhibited age-related changes earlier than males is consistent with the general finding that biologically, females exhibit earlier growth, maturation [88], and senescence [89] relative to males.

3.5.3. Ears

Ferrario et al. [86] analyzed 3D data from 50 soft tissue landmarks from a sample of white northern Italians (240 females and 351 males, aged 6–40 years; $n = 591$). Although it would be expected that growth would occur from childhood up through adulthood, it is noteworthy that ear dimensions continued to increase in size after age 30 years. Ears were larger in males when compared to females of corresponding age.

Brucker et al. [85] conducted a morphometric study of the external ear, analyzing data collected from a randomly selected sample of 89 females (aged 19–65 years) and 34 males (aged 18–61 years). The authors found statistically significant sex differences whereby male ears were longer and larger than female ears, with the exception of earlobe height and width, which were comparable. There were statistically significant differences in total ear height related to age—ear height increased with age and this change was mainly attributed to increases in earlobe height. Earlobe width decreased significantly with age.

3.6. Implications

This literature review synthesized findings from various studies regarding the ways in which the craniofacial complex changes with adult age, and the factors that influence the changes. The information provided is relevant to the forensic sciences where facial sketch artistry, facial recognition, and or adult facial age-progression are concerned. For example, our research team is currently engaged in projects focusing on 3D modeling of adult heads and faces, computer age-progression techniques, and automated face-recognition systems [57], for purposes of identifying adult missing persons or fugitives after several have passed since the "most recent" photograph was taken.

In beginning one of our projects, we required up-to-date information regarding naturally occurring adult age-related craniofacial morphological changes; hence, we conducted this literature review study. The information we found, presented here, was vital in initiating the work for developing and testing algorithms to be used for predicting what an adult head and face at one point in time might look like 5, 10, or >20 years later. Analyzing quantifiable data on aging landmarks that represent locations of rhytidosis (skin sagging), ptosis (wrinkle formation), as well as craniofacial and dentoalveolar change, may ultimately reveal what, if any, aspects of aging can be effectively predicted by computer models, and what aspects of aging remain best predicted from an artistic or intuitive standpoint.

Our interdisciplinary research, teaming computer science with anthropology, has resulted in a greater understanding of adult craniofacial age-related changes in general. Moreover, it is forming the basis for our work in developing and testing the use of computer technology for quantifiably predicting adult facial age-progression rates and patterns. Adult facial age-progression data may, in due course, lead to promising techniques of human identification via computer automated face recognition as well as possible improvements in age-progression in forensic sketch artistry.

4. Conclusions

This study showed that there are certain noticeable, generally agreed upon skeletal and soft tissue age-related shape, size, and configuration changes in individuals over the course of the adult lifespan. We can predict general ages at which certain changes occur or appear. We also know that particular biological and environmental factors can influence aging, either delaying or expediting the process. There are also features unique to each individual that can affect the appearance of the aging head and face. This paper (1) provided an up-to-date summary of examples from the literature on adult age-related craniofacial aging, with a discussion detailing particular changes, and (2) obviated the benefits of an interdisciplinary approach to literature reviews, specifically where adult craniofacial age-related changes are meaningful to computer science research and forensic science applications.

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