Three-Dimensional Facial Scanning: A Screening Tool for Sleep Apnea?

By Regina Patrick, RPSGT

Scientists have long noted that a large neck circumference and retrognathia (i.e., receding chin) are risk factors for obstructive sleep apnea (OSA). The former can be determined with a simple tape measure. The latter can be measured on x-ray images (i.e., radiographs). Scientists have recently demonstrated that three-dimensional (3D) facial scanning may detect more subtle features of the head such as width and length of the lower jaw, width of the face, and distance between the eyes that could be used to identify people who may be at risk of sleep apnea. This technology could potentially be used to more accurately detect people who may be at risk of having OSA.

In OSA, soft tissues such as the tonsils and adenoids intermittently block the upper airway as a person sleeps. Airflow is reduced or fully obstructed, thereby causing a cessation in breathing. Scientists believe the blockage occurs because the upper airway muscles relax excessively during sleep, which allows soft tissues such as the tonsils and adenoids to be drawn into the airway and thereby block airflow.

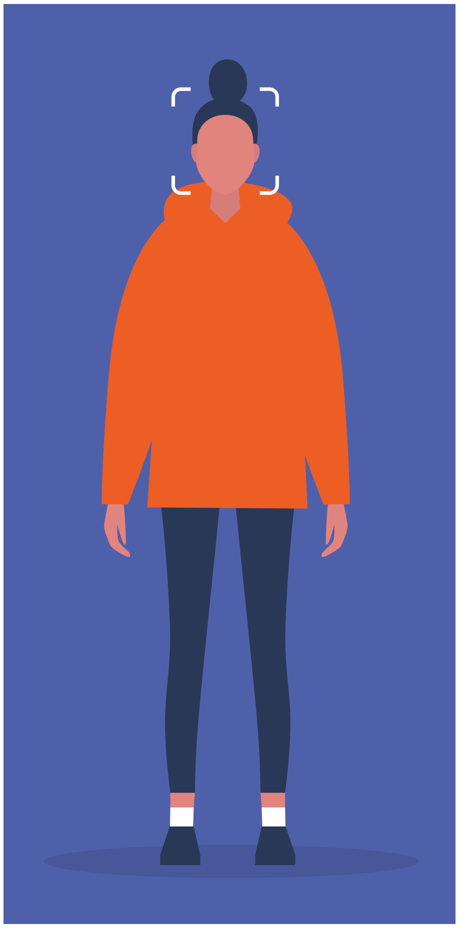
In the past, researchers have used frontal and lateral radiographs of the head (which give two-dimensional [2D] information) to determine which anatomical features of the skull could be used to predict the probability that a person has OSA.[1,2] Features such as retrognathia, maxillary retroposition (i.e., the upper jaw sets back farther than normal), displacement of the hyoid bone (located below the chin and above the thyroid cartilage) to a lower-than-normal position, and a smaller anterior neck space have been associated with an increased risk of OSA. Relationships between bony landmarks of the skull have also been used to determine the risk of OSA. Some landmarks are the sella (i.e., a depression in the sphenoid bone at the base of the skull that contains the pituitary gland), the nasion (i.e., the depression above the nose just below the eyebrow), the A point (i.e., the most concave point at the front of the maxilla), and the B point (i.e., the most concave point on the mandibular midline). The sella-nasion-A point (SNA) angle (which is normally 82°) is used to assess whether the maxilla is too far forward (>82°) or too far backward (<82°), relative to the mandible. The sella-nasion-B point (SNB) angle (which is normally 80°) is used to assess whether the mandible is too far forward (>80°) or too far backward (<80°), relative to the maxilla. The A point-nasion-B point (ANB) angle (which is normally 2°) is used to assess malocclusion (i.e., misalignment between the teeth of the maxilla and mandible; for <2°, the mandibular canine and first molar are situated forward of the maxillary canine; for >2°, the first maxillary molar is situated forward of the mandibular molar).

Some drawbacks of using radiographs to measure craniofacial structures are lateral structures may be enlarged or distorted, accurately determining landmarks may be difficult because of overlapping structures, and landmarks that are visible on the lateral image may not be visible on the frontal image. Therefore, scientists have investigated other imaging techniques that could be used to detect physiological features that are associated with OSA. A promising imaging technique is 3D photography. A 3D photograph of a person's face allows a viewer to rotate the image horizontally, vertically, and obliquely. This feature allows landmarks on the surface of the face to be measured geodesically and linearly. A geodesic measurement is the shortest distance between two points on a curved surface. A linear measurement is the shortest straight distance between two points. For example, in a half-circle with one end of its diameter labelled point A and the other end, point B, the linear distance would be the straight line between A and B (i.e., the diameter) and the geodesic distance would be the curved line between A and B (i.e., the half circumference).

Three-dimensional stereo scanning and 3D laser scanning are two types of 3D facial scanning techniques. In 3D stereo scanning, a person sits before a series of cameras and

flash lights that are placed to the left, front, and right of the individual. In this manner, images of the person are obtained from ear to ear. The images of the cameras are combined to form a 3D image. In 3D laser scanning, a single camera is used with a laser probe. The probe emits a thin laser stripe to measure changes in the facial surface. The camera contains a sensor that records the changing distances in the laser stripe in x, y, and z points as the camera is passed horizontally from ear to ear. (The x-y-z points collectively form a "point cloud.")

Once the 3D image is formed, it can be manipulated with software so that a person's face can be viewed at different angles horizontally, vertically, or obliquely. In addition, the image can be presented with texture (i.e., features such as facial hair, skin tone, and eyebrows), with normal shading (i.e., textures such as facial hair, eyebrows, and skin tone are removed [the skin appears white-gray or other non-flesh tone]), or as a point cloud image (which can appear somewhat "speckled" or "meshy").



In a recent study, Australian researchers Peter Eastwood and colleagues[3] examined which craniofacial measurements best predicted the presence and severity of OSA. They analyzed the facial surface by using linear distances and geodesic distances on

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3D photographs. The investigators obtained 3D photographs of adults with and without OSA. The presence of OSA was based on the apnea-hypopnea index (AHI), the number of apneas/hypopneas per hour: no OSA, (AHI, <5), mild OSA (AHI, 5 to <15), moderate OSA (AHI, ≥15 to < 30), and severe OSA (AHI, ≥30). They measured linear distances and geodesic distances between 24 anatomical landmarks.[3] These distances were compared to the measurements directly obtained with calipers.

Compared to using linear measurements (obtained from the frontal view), the geodesic measurements (obtained from the lateral 3D view) significantly improved the scientists' ability to accurately identify individuals with OSA (accuracy rate of 86%) and without OSA (accuracy rate of 89%). When combining the linear and geodesic measurements into a specialized mathematical formula (i.e., algorithm), the predictive accuracy was increased to 91%. The authors also found that the width and length of the lower jaw, the width and length of the face, and the distance between eyes could be used to distinguish between people with and without OSA. Based on these findings, Eastwood suggests that 3D photographs of the face could be used to predict OSA and that geodesic measurements can enhance the predictive ability.

Other research, although not focused on OSA, has similarly demonstrated that geodesic measurements on 3D images are more accurate than linear measurements on 2D computed tomography images of craniofacial features. For example, Bruno Gribel and colleagues[4] imaged intact human skulls with cone-beam computed tomography (CBCT), which provided a 3D view of the bones. By using a caliper, they directly measured the distances between 12 points, and compared these measurements with the CBCT measurements and with the 2D computed tomography measurements. They found no statistically significant differences between the CBCT and direct measurements but did find significant differences between all 2D measurements and direct measurements. Zogheib and colleagues[5] measured distances between 15 soft tissue facial landmarks on 3D images and 2D photographs of young to middle-aged volunteers with normal craniofacial features. The measurements of both types of images were compared to the standard measurements used clinically. They found that the 3D measurements were closer to the standard clinical measurements than were the 2D measurements.

Eastwood did not examine the impact of race on OSA with regard to craniofacial structures. However, some research indicates that race can impact OSA prediction. For example, Richard Lee and colleagues[6] used anthropometry (i.e., measurements of the size, weight, and proportions of the body), cephalometry (i.e., measurements of the dimensions of the head), and polysomnography to explore differences in craniofacial structures and obesity between Caucasian patients and Chinese patients with OSA. For subgroup analyses, both groups were matched for body mass index (BMI) and for

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OSA severity. The researchers found that the BMI was similar between the two groups. OSA was significantly more severe among the Chinese patients than among Caucasian patients (AHI: 35.3 vs. 25.2 events/hour). Compared to the Caucasian patients, Chinese patients had more craniofacial bony restriction such as a shorter cranial base, maxilla, and mandibular length. These differences remained, even after correcting for differences in body height. When focusing on OSA severity between the groups, Chinese patients had more craniofacial bony restriction, but Caucasian patients were more overweight and had a larger neck circumference. The ratios of BMI to the mandibular size or BMI to the maxillary size were similar between the two groups. Lee suggests that craniofacial factors and obesity contribute differentially to OSA in Caucasian and Chinese patients.

Many studies[3,5] using craniofacial 2D measurements on radiographs or geodesic measurements on 3D photographs to assess OSA risk have involved primarily European individuals. If cephalometric findings common for European individuals are used for all races, subtle racial differences in craniofacial structures could potentially result in OSA remaining undiagnosed in non-European individuals. However, the extent that racial features associated with an increased risk of OSA are reflected on 3D photographs has not been examined in depth.

Despite widespread information about OSA among clinicians and the availability of effective treatments, many people with OSA remain undiagnosed and therefore untreated. Increased screening with tools that are easy to administer and cost-effective such as 3D photography could potentially be used to detect people who may have undiagnosed OSA. However, more studies are needed to examine how this technology can be used effectively to detect people with OSA, especially among people of different races.

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a Note: The 24 points used in the Eastwood article

Left and right frontotemporale (Ft)

Glabella (G, the most prominent point in the middle of the forehead)

Left and right external eye corner (Ex)

Left and right internal eye corner (En)

Nasion (N)

Left and right tragus (T)

Left and right alare (Al)

Pronasale (Prn)

Subnasale (Sn)

Left and right gonion (Go)

Left and right outer corners of mouth [chelion (Ch)]

Midpoint where lips meet [stomion (S)]

Gnathion (Gn)

Menton (Me)

Left and right Nk point

Cr point