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3D IMAGING IN ORTHODONTICS: TECHNIQUES, USE AND LANDMARK IDENTIFICATION

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Abstract

When counting all the different kind of tools available for orthodontists in their daily routine, imaging definitely has to be mentioned as it is of huge aid in evaluating and recording size and form of craniofacial structures. The development of imaging technologies led, in the last few years, to the introduction of new kinds of technologies such as the three-dimensional ones. 3D devices allow to have the perception of depth on a 2D surface. Nowadays, different kinds of devices have been applied in different fields and, of course, also orthodontics has begun to take advantage of this new kind of technology.

In particular, the use of 3D devices in orthodontics has two different purposes: on one side to reproduce teeth's shape and cast and on the other side the facial imaging, meaning a 3D picture of the face that, by using some kind of techniques, allows the recognition and the measurement of certain landmarks and their eventual superimposition to check on changes generated by growth or orthodontic treatment.

Discussion

There are several applications of 3D imaging in orthodontics, as well as different techniques and devices.

In general, the production of a 3d image requires several steps including the use of mathematics (in order to frame the chosen object), its pixelation (in order to give it a texture), its shading and lightning (to make it more real) and its rendering (to make the picture viewable on a screen).

3D imaging of the teeth

Between the most common techniques used in 3D imaging of the teeth there are a few noteworthy such as 3D CT scanning and 3D laser scanning and intra-oral dental scanning. They all have a lot of positive effects but each one can have different issues such as the exposure to high doses of radiation, limited resolution or difficulties in capturing due to the long time needed, to the patient movements etc.

There are several application of 3D in the imaging of the teeth: first of all it's a reliable way to archive study casts, then they can be used to document treatment progresses, to analyze intra- and inter-arches relationships, to simulate extractions and space closure, to prefabricate archiwires and to construct aligners.

3D facial imaging

Vision-based scanning techniques are based on the idea that much of what is diagnosed in facial aesthetics need to be related to the deeper structures of bone and muscle; as a result of that, it can be feasible to investigate the face at its surface level only and that's what those techniques do. To name a few: structured light techniques, stereophotogrammetry, 3D Facial Morphometry etc

The most popular medical 3D surface acquisition system is stereophotogrammetry: a fast, non-invasive and user-friendly means to produce accurate 3D images. Stereophotogrammetry is a technique in which two cameras paired as a stereopair photograph an object from two different coplanar planes. Those data are then elaborated in a complex algorithm that convert the two 2D images in a 3D photo on which a huge number of measurements can be done. This technique showed good results not only in face imaging but also allowing the recognition of different facial landmarks, the measurement of linear and angular values and the detection of changes in face morphology.

Whereas stereophotogrammetry requires two cameras, in the structural light technique only one image is used and the acquisition is based on light: by illuminating the scene, the position of the illuminated points on the acquired image is compared to the position of the light on the scene and those coordinates allow the 3D reconstruction of the image.

3D techniques can be used in different phases and for different purposes in orthodontics:

a)*Diagnosis:* their role in diagnosis can be easily understood as orthodontic diagnosis is based, for a huge part, on extra-oral examination. They can therefore help the diagnosis of facial deformities and their exact location enriching data given from radiographies, they can reduce the amount of time spent by the patient for clinical assessment and give the clinician a way to recall and re-observe the patient three-dimensionally (the image can be rotated in any direction) without having him back for a visit.

b)*Assessment of facial changes*: 3D pictures can be used to observe the facial changes due to growth or orthodontic/surgery treatment by superimposing two or more pictures

c)*Landmarks identification*: some facial landmarks (on soft tissues) can be identified and used both for diagnosis and for comparison after growth and/or treatment

d)*Communication tool*: to show the patient deformities, asymmetries and other facial patterns in order to motivate him before and during the treatment

Soft tissues landmark detection and reproductibility

When using stereophotogrammetry, one of the biggest outcomes is the identification of landmarks on scanned images to identify facial morphology. In fact, even though a lot of soft tissue landmarks can be used, it was not clear whether they were reliable and repeatable and whether their identification was subjected to the examiner charged to detect them. Different studies verified the reproducibility of facial landmarks on 3D images.

Dindaroglu and his team led a study comparing measurements taken on 3D and 2D (both on 2D photogrammetry and 2D direct anthropometry) images of the same subjects taken the same day in the same conditions in order to evaluate the accuracy and reliability of 3D stereophotogrammetry. He stated that measurements using 3D stereophotogrammetry were consistent with the 2D ones. Moreover his study showed intra- and inter-examiner reproducibility.

Baysal's research on the intra- and inter-examiner reproducibility of 19 soft tissue points on stereophotogrammetry showed an high reproducibility and reliability of all landmarks examined, both in inter- and intra-examiner comparison with less than 1 mm between repeated markings.

Also Othman carried a similar study by using a 3D camera for full face imaging and by detecting and measuring 24 facial soft tissue landmarks. He checked the intra-operator reproducibility (by a self-double-check after two weeks) and the inter-operator reproducibility. His statistical analysis showed that the intra-examiner reproducibility was acceptable whereas the inter-examiner reproducibility needed further studies to be assessed. He also noticed that Nasion was the most reproducible point after superimposition even though other studies found its position on the y-axis less reproducible (maybe due to the difficulty in placing the patient in a natural head position). Right palpebrale inferius appeared as the least reproducible landmark, maybe because the area around the eye being ill-defined may lead to imprecise reproducibility of measurements.

Another similar study with the same purposes is the one led by Ceinos and his team. They recorded the distance between seven different landmarks including not only soft tissue's ones but also dental measurements: the incisal edge (IE) and the distal point of each canine ($DC_{r\ or\ l}$) in order to evaluate the inner part of the dental corridor. The results showed that the system they used provides reliable 3D images of the face and allows the recognition of reproducible intra- and inter-examiner landmarks for what concerns the facial ones. As regards dental landmarks, the measurements involving the inner part of the dental corridor showed a lower ICC, meaning that they cannot be considered reproducible.

Naftel led a research to assess whether 3D landmark detection could be automated using a combination of active shape model-driven feature detection and stereophotogrammetric analysis. In particular, using this system, he analyzed the changes in soft tissues automatic landmarks induced by mandibular repositioning with bite blocks concluding that, not only his method is statistically validated, but it also appears to be successful in separating out the changes due to bite block insertion (equivalent to treatment) and changes due to the mandibular physiological growth. He therefore suggested that this could be a method to review the clinical treatment of sagittal malocclusions with respect to its effects on facial soft tissue morphology.

Conclusion

3D devices have a role in helping the orthodontist through his diagnosis, treatment and prognosis procedures. There are a lot of different techniques that can be used depending on the kind of analysis needed and each one has different outcomes, reproducing three-dimensionally different tissues and implicating higher or lower risks for the patient.

Stereophotogrammetry is a technique that showed positive results concerning facial imaging making possible the detection of facial landmarks. Literature agrees on how most of those soft tissues landmarks are not only accurate and reliable but also reproducible.

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