Latest Trends in Prosthesis Application

Presentation of real case of Total Upper Rehabilitation

Emidio M. CENNERILLI*, Serena SANTORO
EGS, San Lazzaro di Savena (BO), Italy

Abstract

This article presents a clear example about how 3D technologies are strongly entering as fundamental elements in the medical field.

In particular, it explores how the use of 3D technologies can implement the dental prosthesis planning and realization by presenting the relationship between the body posture and the digital dentistry in a real total upper rehabilitation with Toronto Bridge. The article provides an overview about 3D scanning technologies, digital smile design and CAD software, focusing the attention on the application of 3D body scanning technologies in the digital dentistry workflow for the analysis of the prosthetic treatment result.

The article concludes that 3D technologies are implementing everyday more and more the work of both dentists and dental technicians by providing more precise and accurate working protocols. Moreover, the application of 3D body scanning in this field is a new trend, which elevate the pre and post treatment analysis at a very specific level, which allows to understand the cause and the effect of each single pathologic case.

Keywords: 3D body scanner, 3D technology, 3D software, CAD/CAM, Digital Dentistry, Prosthetic treatment, Total upper rehabilitation, Stomatognathic apparatus, Body posture analysis.

1. Introduction

Medicine is going digital and the proof is that nowadays more and more areas, such as dietetics, dermatology or orthopedics or dentistry take advantage of 3D scanners during the phases of diagnosis, treatment and control.

The literature has widely demonstrated that an incorrect occlusion stimulate the nerve pathways through abnormal activation of the mastication muscles, which are part of the muscle chain of the postural system. Therefore, once corrected the occlusion, also the posture should change. The integration of the 3D body scanner in the digital dentistry workflow gives the opportunity to improve the study of the relationship between teeth, lips and posture.

This paper concerns the application of 3D technologies in the digital dentistry; by presenting a real application case, the aim of the work is to give an overview about the relationship between stomatognathic apparatus and digital dentistry, as well as to show all the benefits arising from the use of a new protocol in the dental field. In particular, by focusing the attention on 3D body scanning technologies, the entire process of total upper rehabilitation with Toronto Bridge will be presented – by comparing the patient scans before the treatment and after.

2. Scanning technologies overview

There are several ways to obtain a 3D scanning of physical objects. All of them require to gain information on the spatial position of the surface points of the object. This can be achieved either by physically touching the object with a sensor or by using sound waves or light.

Light in particular is very often used because it is accurate, fast, reliable and non-invasive. Indeed, a touching sensor can damage the object or get damaged during the scanning process.

2.1. Light-based scanning technologies

Light-based scanning technologies for short-distance scanning are mostly based on two main categories: laser light and structured light.

---

* egs-info@egsolutions.com; +39 (0)51 6049700; www.egsolutions.com

2.1.1. Laser light 3D scanner

In the laser light systems, a laser beam or laser stripe is directed onto the target, where it will be deflected according to the characteristics of the target surface. One or more sensors will then intercept the reflected beam. From the relative position between the light source and reflected beam, the position, the distance and the orientation of the target surface can be mathematically calculated.

Laser-based scanners have a high and vastly adjustable accuracy, but the time required to complete a scan is strongly and directly dependent on the quality expected. Laser scanners acquire data point by point, so for any increase of the amount of points scanned there is a proportional increase in the amount of scanning time required. For extremely detailed scan, the acquisition time can be so long as to generate motion related problems if the object or the scanner moves or are displaced even slightly during the scan. Moreover, laser, unlike structured light, can be dangerous and might require special precautions during the use.

For these reasons, to analyze the posture of the patient has been chosen to proceed with a structured light scanner.

2.1.2. Structured light 3D scanner

Structured light systems work with standard light instead of lasers, and project a stable and defined series of light patterns on the target object. Cameras then capture the distortion of the reflected image, so that the position of every point on the target surface is calculated from the distortions of the patterns.

Structured light require multiple scans to thoroughly acquire every surface of the target object. The different scans are then merged together into a single model. Despite the multiple scans required, structured light scanners are not slow. This is possible because the CCD sensors in a structured light scanner can acquire information on multiple points in the field of view at once, instead of just one at a time.

As a final result, the structured light technology is very fast and effective to scan low curves surfaces, and highly detailed organic surfaces.

3. Stomatognathic apparatus and digital dentistry

The stomatognathic system is not an isolated system, but is part of the face and body system. The body is connected from the head to foot by five fascial muscle chains, which work together [1]. In one of these fascial muscle chain, the Anterior Median Chain, there is the Hyoid bone (see figure nr. 1 below), which, through the Supra Hyoid muscles, is connected to the head and the mouth. In the same way, through the Sub Hyoid muscles, is connected to the shoulders (see figure nr. 2 below).

Therefore, it is possible to suffer of muscle tension that, from the mouth and through the hyoid bone, disturb the balance of the rest of the body (and vice versa).

These muscle tensions can generate muscle-contraction headache, back pain, and loss of muscular efficiency.
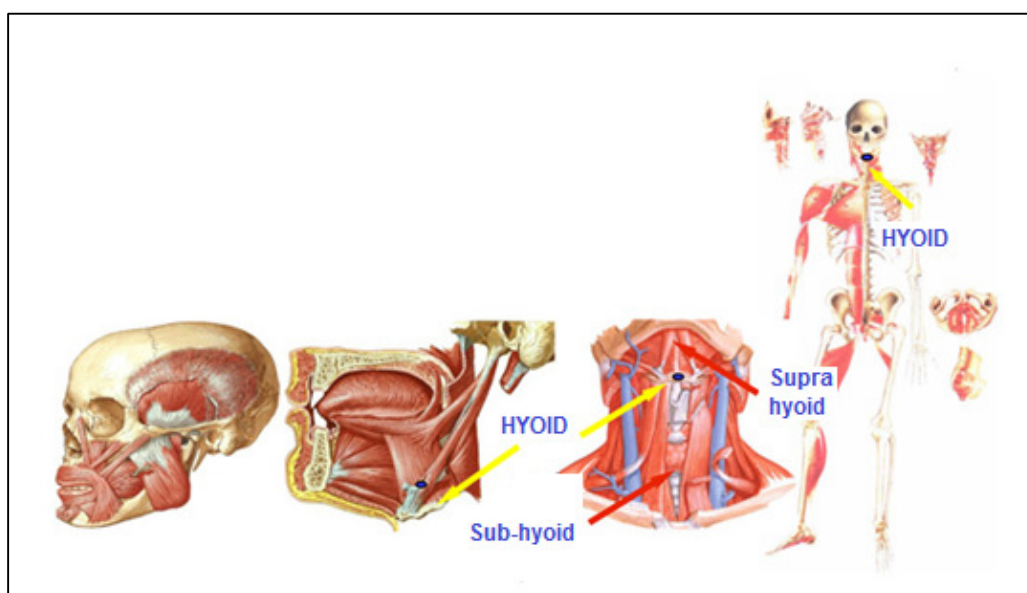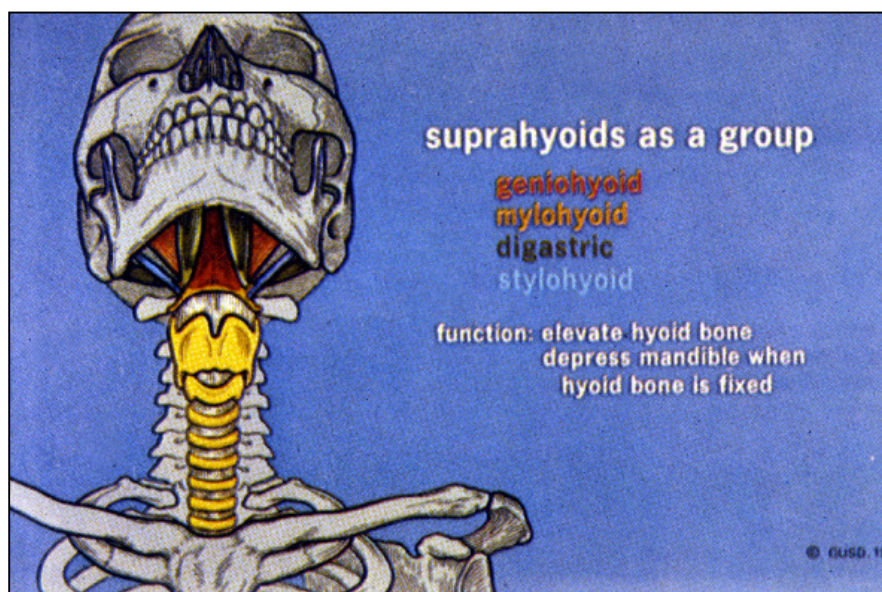

Fig. 1. Fascial muscle chains.

Fig. 2. Supra Hyoids as a group.

The body is considered in rest position (commonly known as "body posture"), when an equilibrium relationship between its parts is established when we are relaxed, standing, with the eyes looking at the horizon.

It is also well known that column, shoulders and pelvis generally have spinal curvatures with light opposite inclinations between the shoulders and the pelvis, which compensate each other.

Therefore, the goal of the body is not the research of symmetry, but the research of the body balance; it means that the key points of the body will be vertical to the floor and in compliance with the compensatory asymmetries between the right and left side of the body (see figure nr. 3 below).
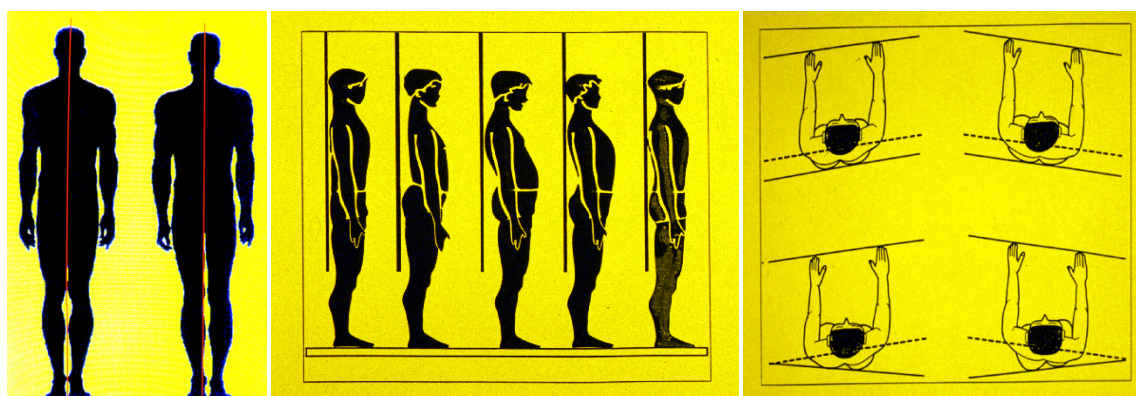

Fig. 3. Body balance.

3.1 The mouth and the body posture

The research of balance is a logic also common in the mouth, indeed, the two frenula, in physiological position will be aligned, but, as in the body, we will have inclinations of the anterior group and different curves of Spee and Wilson between the right and left side, which compensate each other.

The stomatognathic system is an integrated part of every single physiological body posture, and therefore it involves many differences between people according to their biotypes and asymmetries.

So, analyzing the body, the face and the way muscles work, we have the parameters to design and realize dental prosthesis, which will fit in the best way to the physiology of each human being.

It is important to be in good health, but since each of us is unique and different from others, putting at the center the patient's health means respecting this uniqueness.

3.2 Postural studies

To analyze the posture in the past were used tools such as the posturometer, in order to view the muscle pattern responsible for the body torsions (see figure nr. 4 below).
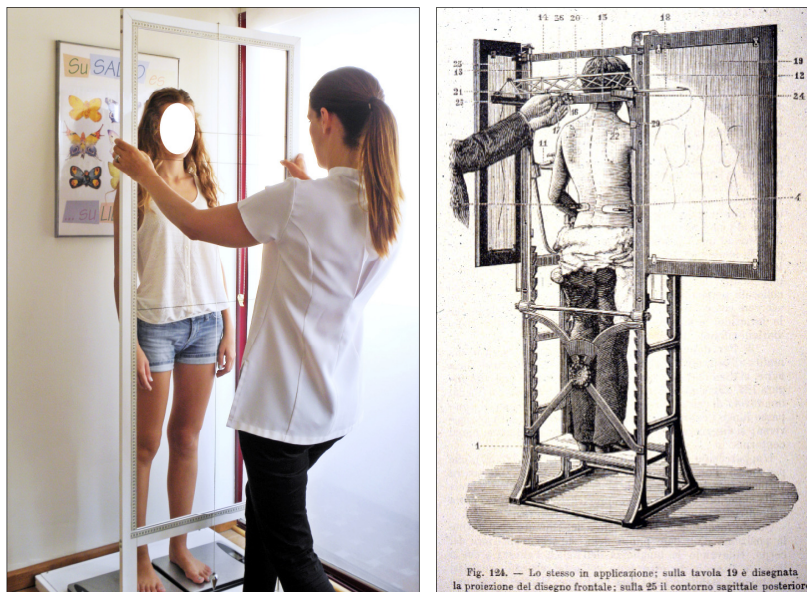

Fig. 4. Posturometer.

Today, thanks to the 3D technologies we can acquire data of the entire body of the patient with a 3D scanner (see figure nr. 5 below). In the digital dentistry, this protocol can be very useful because it allows comparing how the posture vary according to the occlusal aspect. Moreover, the body scanner is able to capture very small details and changes (also in the arts) that the analogical 2D method can not see.

Indeed, the body has to be seen as a single set of muscles: it can not be evaluated in watertight compartments, but only as a single unite.

Fig. 5. 3D scanning for the posture acquisition.

Similarly, the mouth maintains its delicate balance, which is in constant dynamic due to the swallowing, phonesys, chewing and breathing functions. Therefore, we can understand how influent can be every single prosthetic o rehabilitative operation on dental arches, for the stomatognathic balance maintenance. It is possible to exemplify this concept by looking at the following picture (figure nr. 6): if one connection changes, all the other suffer changes too.
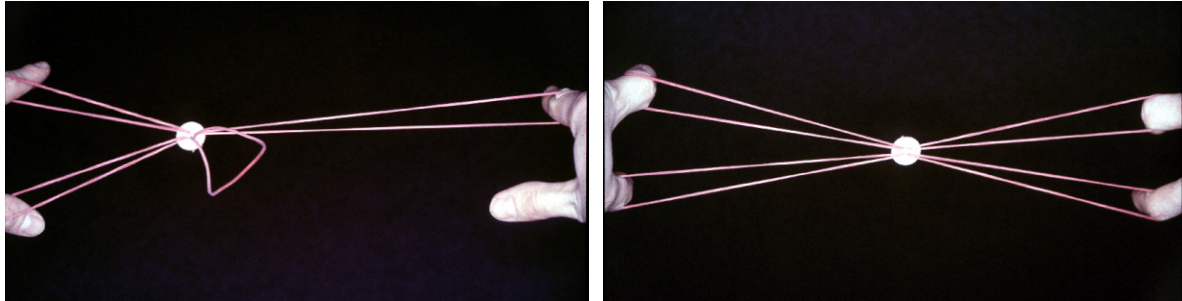

Fig. 6. Example of how the balance changes.

To summarize, we can consider the spine as the main shaft of the body (see figure nr.7 below). The muscles, acting on the column, can be considered as the tie rods of this shaft (whether they are inherent to the column or connected to other body parts). Some of these muscles are synergistic to those that originate from the jaw, whose position and movements are conditioned by the alignment of the teeth: it then creates contrast between the gravity forces and the mechanical stresses.

As a result, a malocclusion may cause an abnormal working of the muscles of the neck with repercussions on the balance of the whole body.

Obviously, the imbalance can follow the opposite way to the one just described. So, the primary survey to do on dysfunctional patient is to establish whether the priority is ascending or descending, by distinguishing cause and effect.
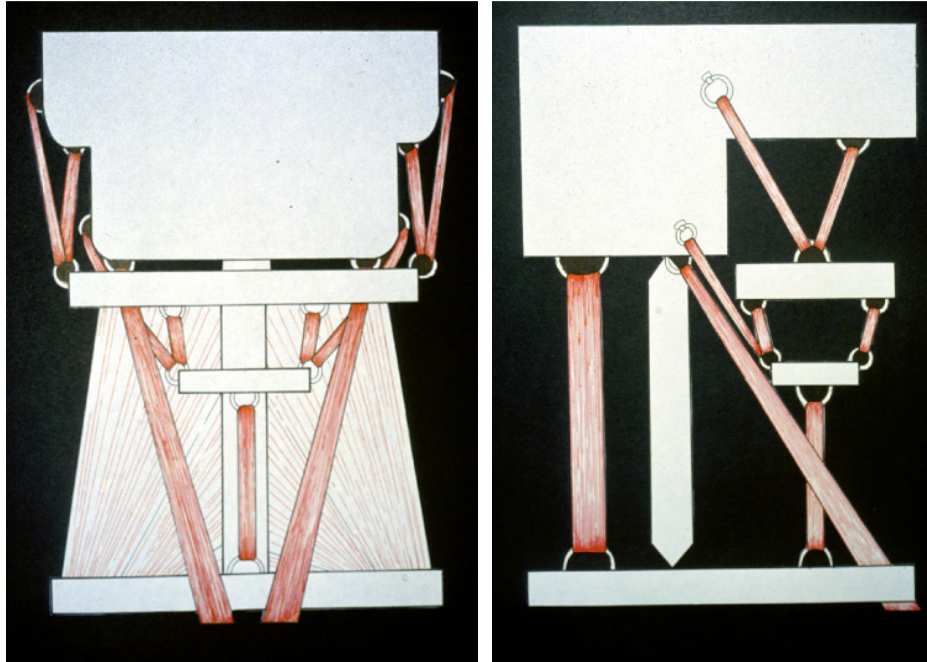

Fig. 7. Example of the body shaft.

3.3 Digital dentistry workflow

New technologies and, more specifically, the digital ones are strongly entering as fundamental elements for the dental prosthesis planning and realization.

In the picture below (see figure nr. 8), we have an overview of the digital dentistry chain. As we can see, technologies allow moving in digital every step of the traditional dentistry workflow. Moreover, with the 3D body scanner it is possible to make analysis on the patient situation pre and post the treatment. In this way, we can have a more efficient workflow, which permits to gain very accurate results by saving time and costs.
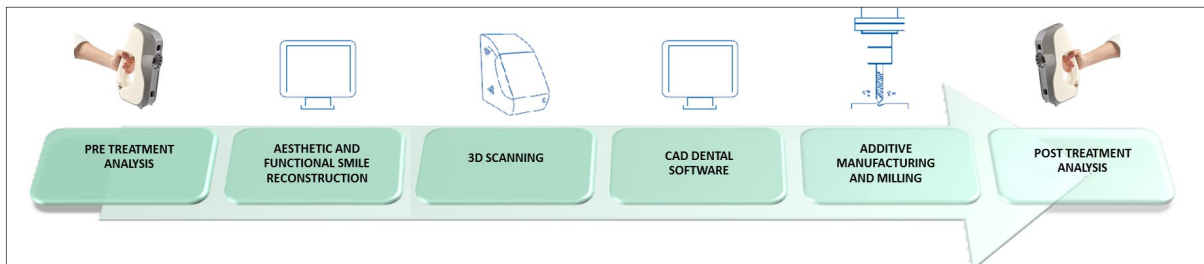

Fig. 8. Digital dentistry workflow.

4. Case history

The case we are going to present here following will analyze in detail the digital workflow of a total upper rehabilitation with Toronto Bridge by focusing the attention on the different postures assumed by the subject according to the prosthetic work considered.

4.1 The scanner

To get the 3D images of the postures has been used the Artec EVA structured light scanner (see figure nr. 9 below). It is an handle scanner designed for accurate, close-in work. It is good for organic shapes acquisition, such as human bodies, because can generates industrial accuracy level results. The 3D scanner Artec EVA combines a projected light and cameras system. By projecting a band of light on a surface, the band suffers distortion according to the surface. The two cameras capture this distortion and reconstruct the exact geometric shape of the element, by creating a cloud of points. This process allows to have a perfect three-dimensional measuring of the element.

The use of this technology is becoming so widespread that nowadays, in order to facilitate the work even to non-experts of technology, there are auto-rotating platforms that further simplify the scanning phase.

Fig. 9. Artec EVA – structured light scanner.

4.2 Analysis of the patient situation before the treatment

The first step of the digital dentistry is dedicated to the evaluation of the patient's situation. In particular, the subject needed a total upper rehabilitation with Toronto Bridge to replace a previous incongruous work.

Therefore, before starting the rehabilitation project, the patient has been scanned in order to acquire the entire 3D image of the posture. As we can see from the picture below, the posture presents abnormal curvatures probably due to the malocclusion (see picture nr. 10 below).
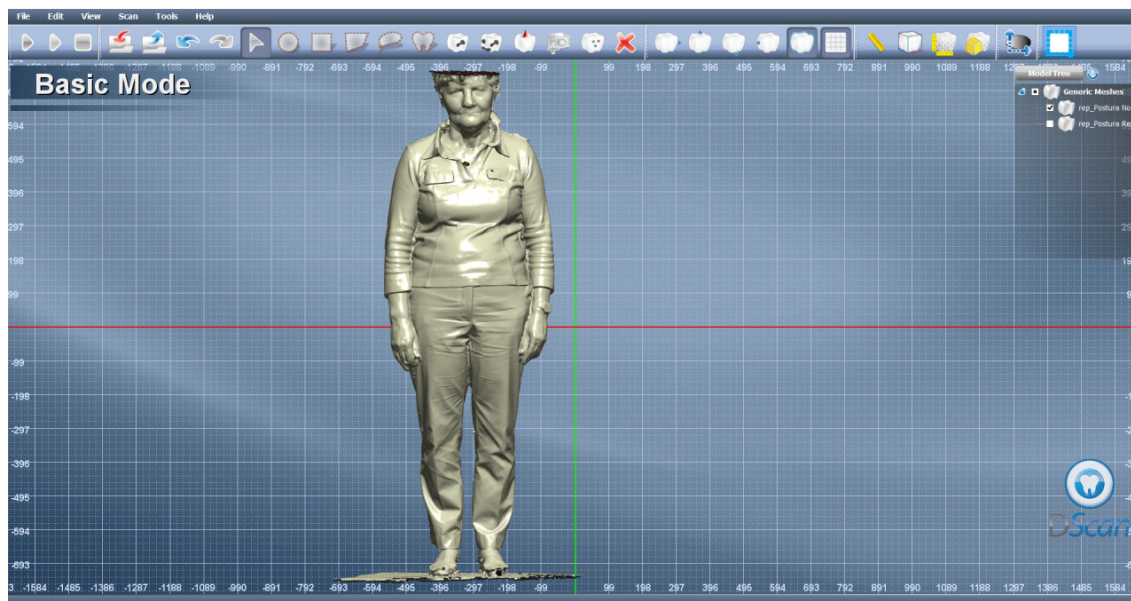

Fig. 10. Posture with the incongruent work: 3D front side.

From the front side it emerges that the head is tilted, the shoulders are not aligned and, consequently, arms and legs compensate for the balance.
In the following images (see picture nr. 11), we have a more detailed vision about how the malocclusion can modify the balance of the subject. In particular, from the right side we can observe that the neck moves forward, the shoulders goes back, pelvis compensates by shifting the center of gravity ahead and feet are retreating as the shoulders.
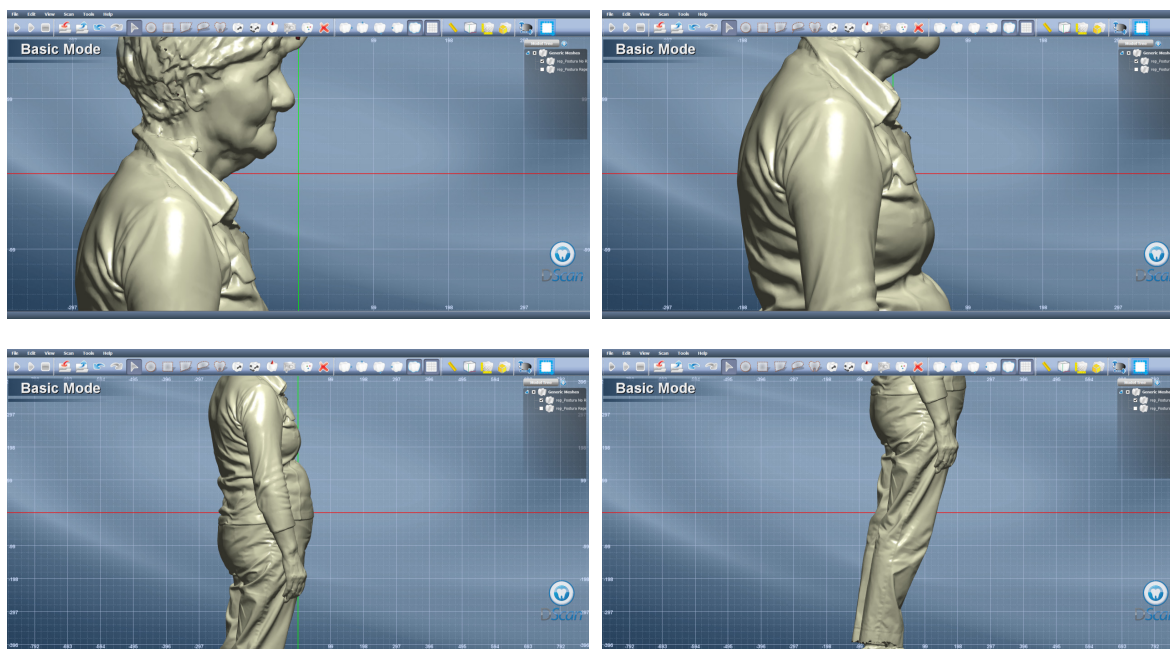

Fig. 11. Posture details with the incongruent work: 3D right side.

According to this analysis, the dentist will be able to elaborate a rehabilitation project, which can help the patient to have a more correct postural balance.

4.3 Prosthesis realization

4.3.1 Aesthetic and functional smile reconstruction

For this kind of relevant rehabilitations, the digital dentistry includes the virtual realization of the smile reconstruction project.

In this case has been used an innovative software for clinic, functional and aesthetic design, the Digital Smile System (DSS). With just two pictures (the smiling face of the patient and the intraoral), through a guided workflow, the software allowed to quickly realize a custom aesthetic test of the virtual smile, contextualizing it in the entire face of the patient, through a self-managed digital elaboration (see picture nr. 12 below).

Fig. 12. DSS: pictures import, alignment and elaboration.

In this phase, digital dentistry and, more specifically, the clinical use of the DSS software represents an incredible advantage for the planning of both the work and the information flow. Indeed, for the dentist will be easier to present to the patient the final prosthetic result and at the same time to provide the necessary information to the dental technician for the execution of the prosthetic treatment plan.

Once completed the previsualization, was prepared the dental arch to be transferred in dental CAD (see picture nr. 13 below).
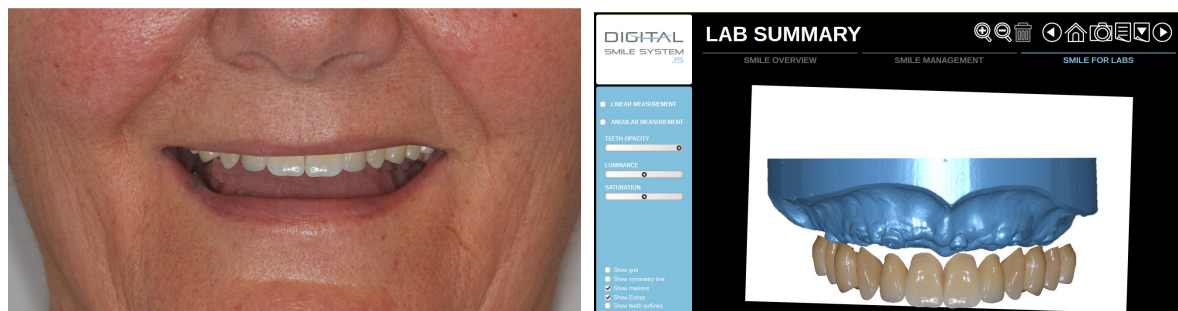

Fig. 13. DSS: End of previsualization and summary report for CAD elaboration.

4.3.2 Mouth 3D data acquisition

After that, the workflow switches to the recognition of the 3D data of the mouth. In particular, the laboratory used a desk scanner with structured light technology (Dscan3 Blue Light) in order to acquire very accurate and precise data from the model (see picture nr. 14 below)

Fig. 14. Dscan 3 Blue Light: 3D data acquisition from the model.

4.3.3 CAD elaboration

At this point, all collected data were injected into a CAD system (DentalCAD 4.0), where was possible to realize the framework thanks to the simple 3D modeling tools and by using the volumes studied in DSS (see figure nr. 15 below).
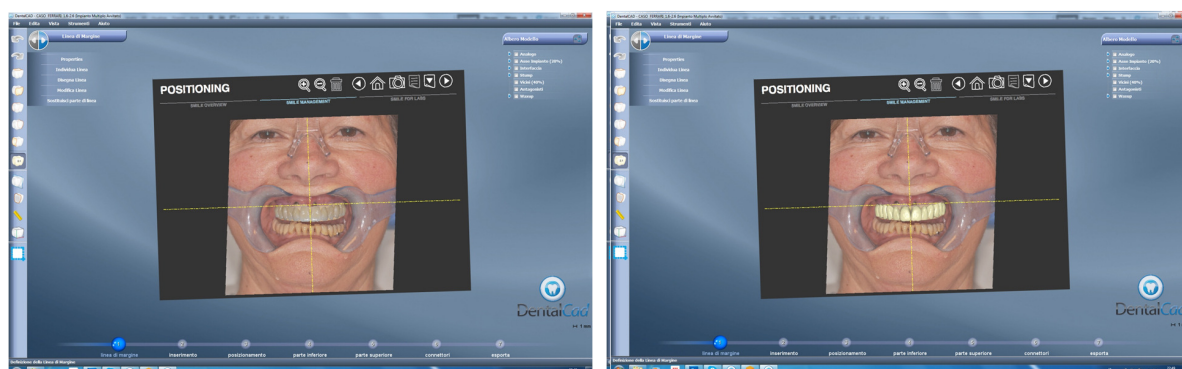

Fig. 15. DentalCAD modeling throughout the volumes studied in DSS.

In order to have a perfect previsualization of the finished work, we also imported the patient's 3D face, which has been oriented in the space thanks to the measurements made in DSS. This step allowed us to study also the occlusal aspect (see pictures nr. 16 below).
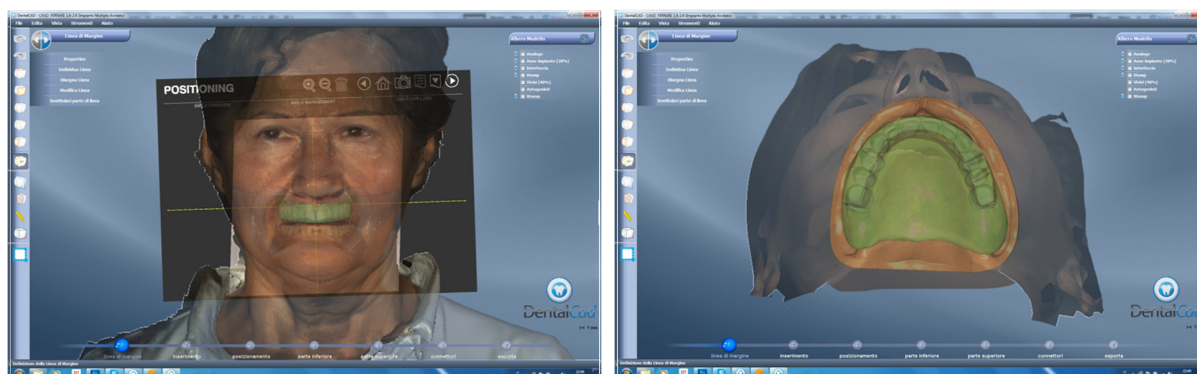

Fig. 16. DentalCAD: occlusal aspects study for before modeling.

The very high quality of the mesh elaborated in DentalCAD, allowed the dentist to print with a 3D printer the framework in PMMA to be proved on the patient. In this way, all those customizations necessary for the execution of the final work were made by screwing the prototype directly into the oral cavity of the patient (see figure nr. 17 below).

Fig. 17. PMMA prototype proof.

At this point, it was already possible to see and analyze the posture changes of the patient. Anyway, in order to make the most reliable analysis, we decided to scan again the patient only at the end of the prosthetic treatment.

Thus, after the check with the prototype, was constructed the substructure that would have supported the teeth installation, according to the volumes tested on the patient (see figure nr. 18 below).
Our goal was faithfully reproduce each aesthetic and functional detail previously determined in digital throughout a simultaneous 5-axis milling machine.
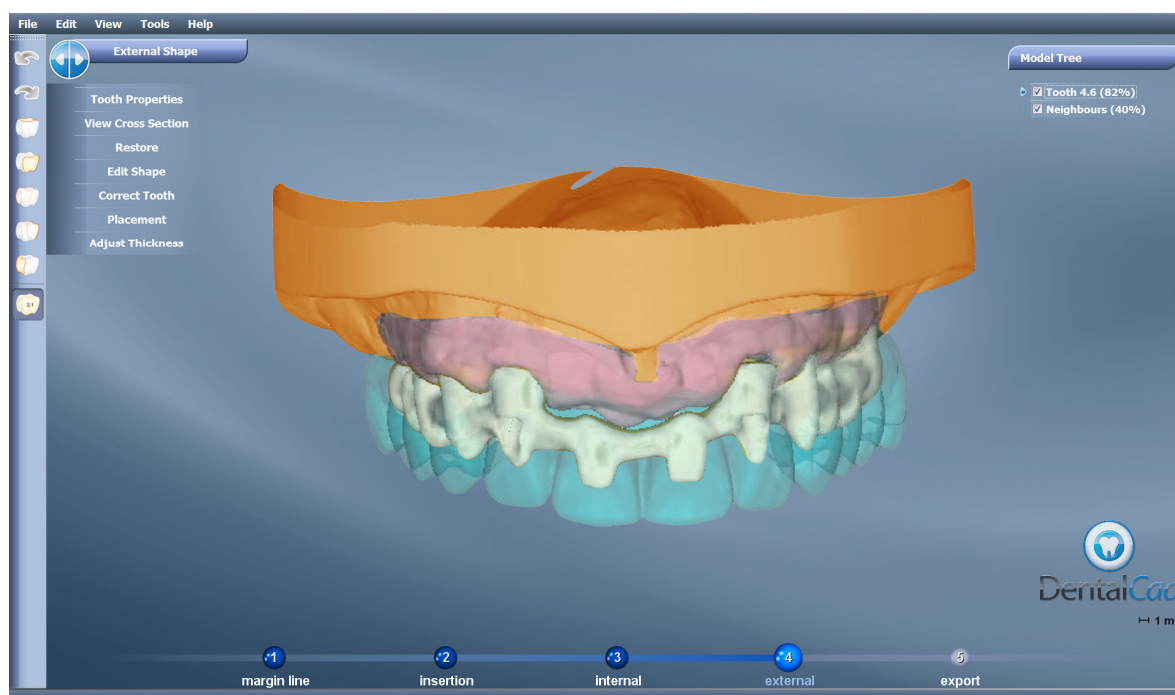

Fig. 18. Substructure creation.

4.3.4 Milling and finalization of the work

After the milling cycle, the product was carefully adapted to the model, in order to finalize the work. By means of these new digital technologies, the dental technician got the opportunity to express and enhance the creativity skills, by focusing on aesthetics finalization and functionality.
As we can see, the final result is perfectly in line with the schedule established with the patient during the aesthetic test of the prosthesis with DSS (see figure nr. 19 below).

Fig. 19. Final work.

4.4 Analysis of the patient situation after the treatment

After the work finalization, another body scanning with the new prosthesis has been made for the postural comparison. As we can see from the picture below (nr. 20), the shoulders have now almost the same height.
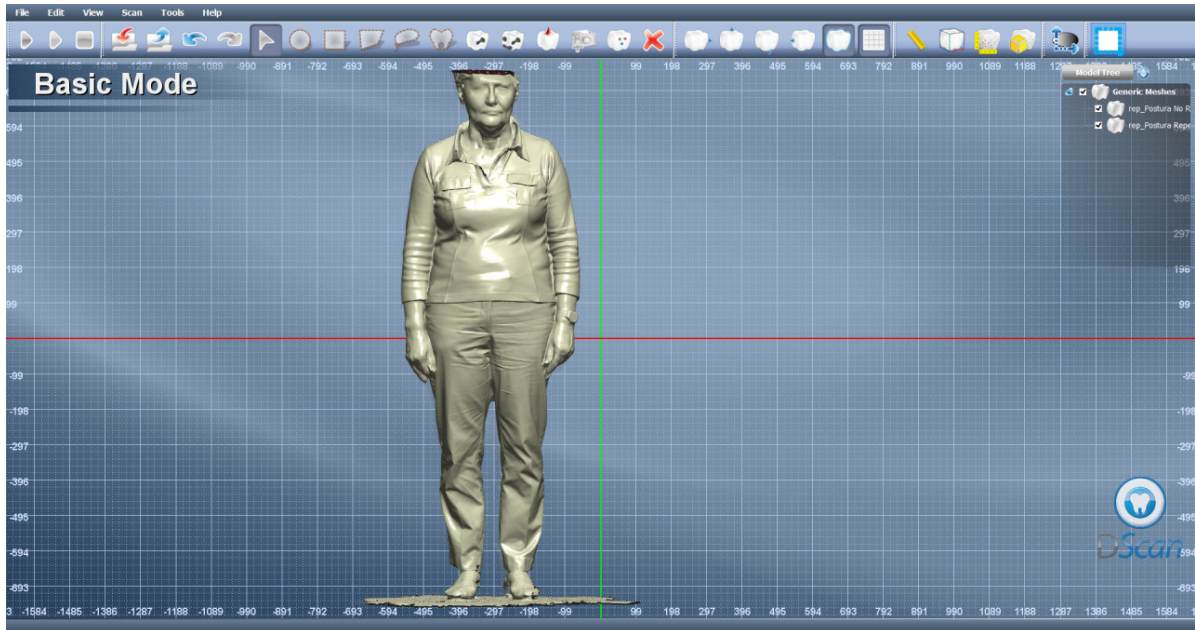
Fig. 20. Posture with the new prosthesis: 3D front side.

Also from the right side, we can observe differences in the posture (see figure nr. 21 below).
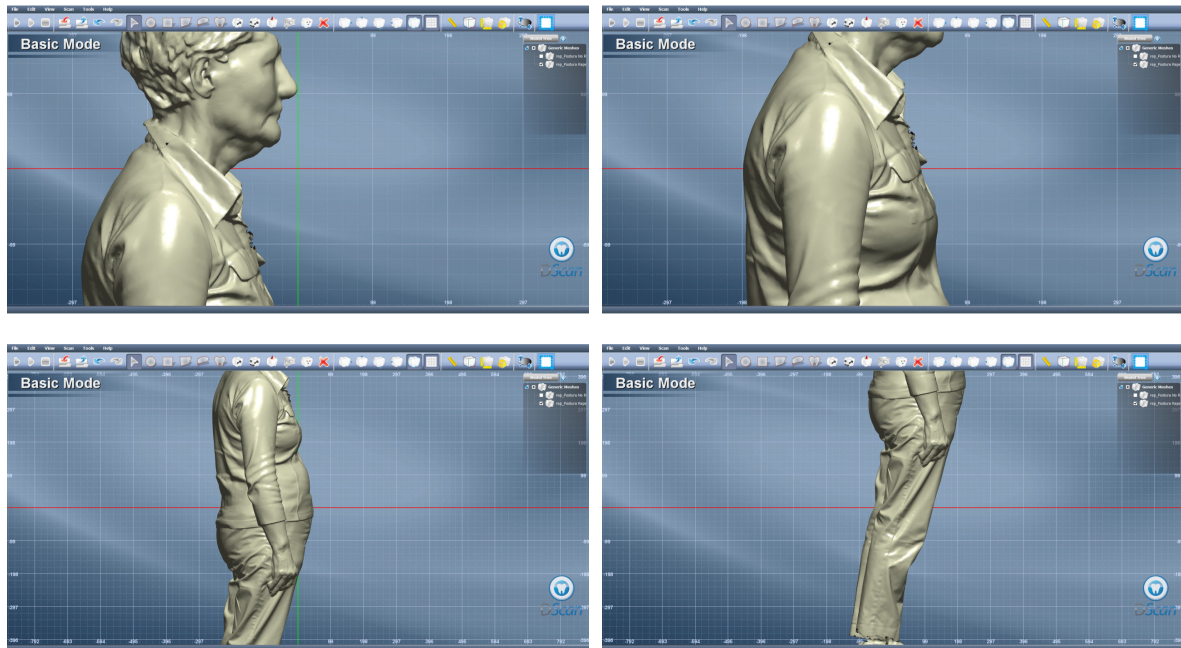

Fig. 21. Posture details with the new prosthesis: 3D right side.

The displacement of the neck is smaller and, therefore, also the shoulders, the pelvis and the legs are more aligned.

Finally, we can make sure that the new prosthetic work has made improvements to the posture of the subject, by overlapping the scans done before and after the prosthetic treatment.

In blue we have the scan made before the treatment and in gray the one made after it. As we can see from the following pictures, the posture made before the treatment hangs toward the right side of the patient (see figure nr. 22 below). In addition, the position of the nose clearly shows that the neck tends to be more perpendicular to the shoulders in the scan done after the treatment (grey one) – figure nr. 23.

Similarly, shoulders, pelvis and legs in the grey scan present a more linear balance comparing to the blue one (pre treatment) – figure nr. 24.
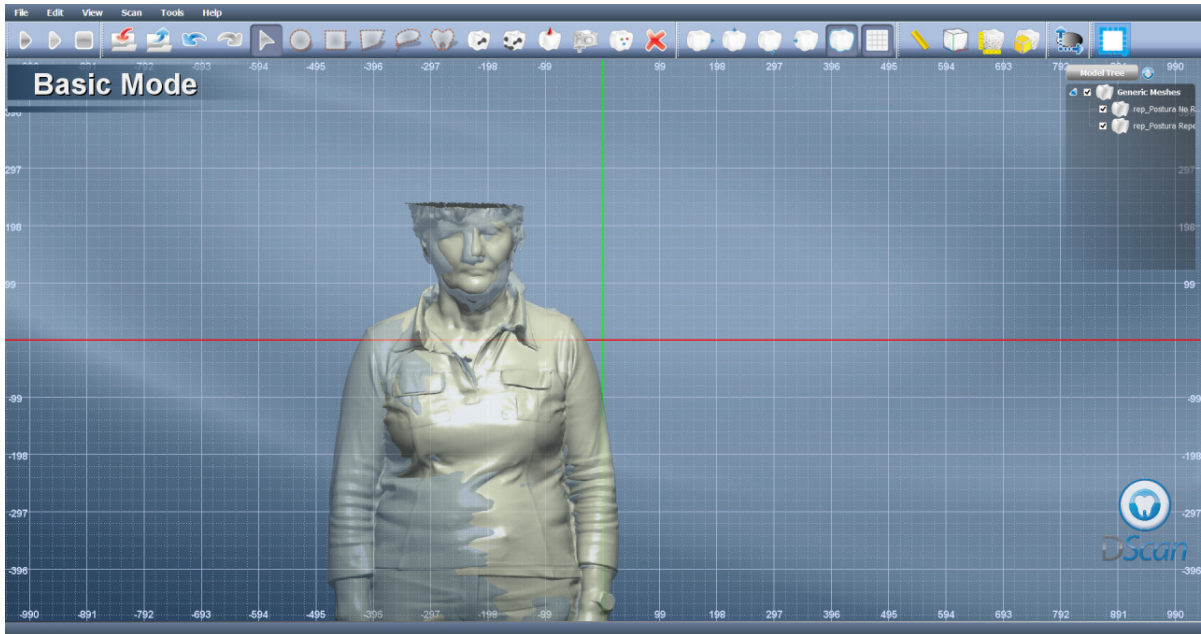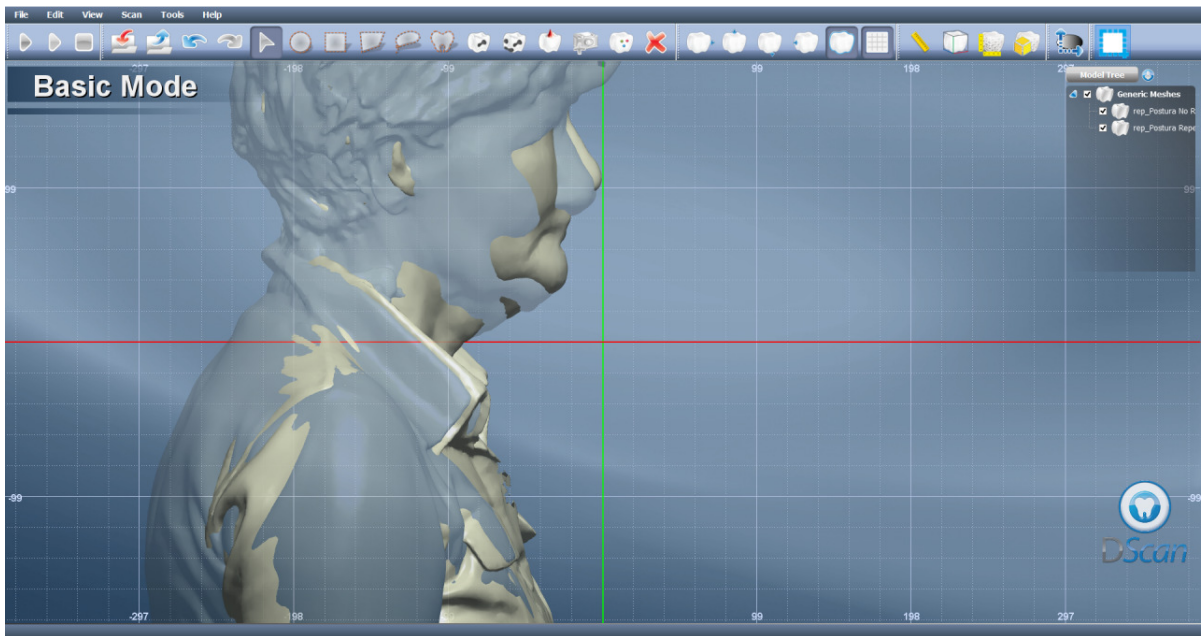
Fig. 22. Postures comparison: 3D front side.

Fig. 23. Postures comparison: 3D right side (nose detail).

Fig. 24. Postures comparison: 3D right side (body and legs).

5. Conclusion

This paper is a clear example about how 3D technologies are implementing everyday more and more the work in the medical industry by providing more precise and accurate working protocols.

In particular, we have seen how the use of 3D body scanner is becoming part of the digital working chain in dentistry. Indeed, it allows not only to analyze the body posture according to the occlusion, but it gives also the opportunity to check if a rehabilitation project can improve or not the posture of the patient.

The Artec body scanner used for this project, has been developed with an innovative hardware and software technology, which allows acquiring with extreme accuracy the face data. For this reason, it is a transverse instrument also useful for other medicine areas (i.e. maxillofacial).

References

[1] *La bocca è parte di un insieme: il corpo,* www.giovannimaver.it/gnatologia/insieme.html, accessed 2014.