Prostheses: Digital Planning and Fabrication

A contemporary design approach for prostheses

Giovanni Maver and Angelo Magni design prostheses with the help of the CAD/CAMCNC-technique. This technique provides a virtual look at the muscles and bones ratio and digital imagery offers precise design options. This method cuts material costs and saves time.

Giovanni Maver
Pedrengo, Italy

Angelo Magni
Fornovo, Italy

Fig. 1 — Initial situation.

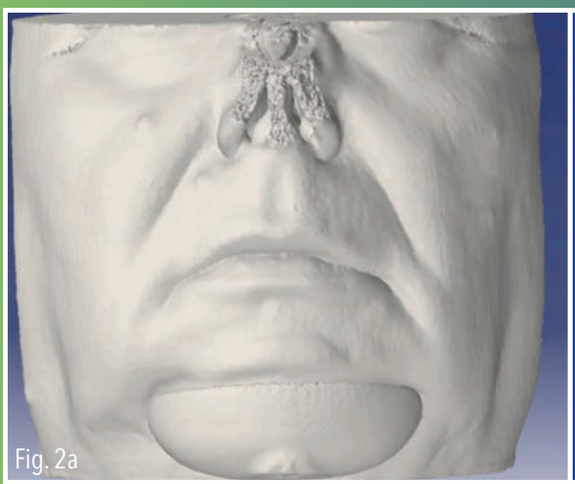


Fig. 2a

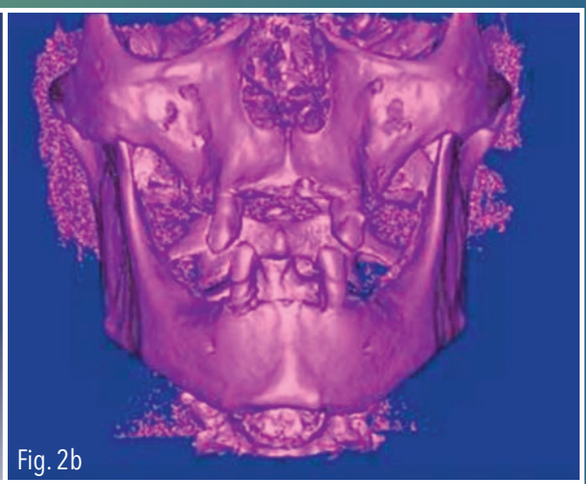


Fig. 2b


Fig. 3a

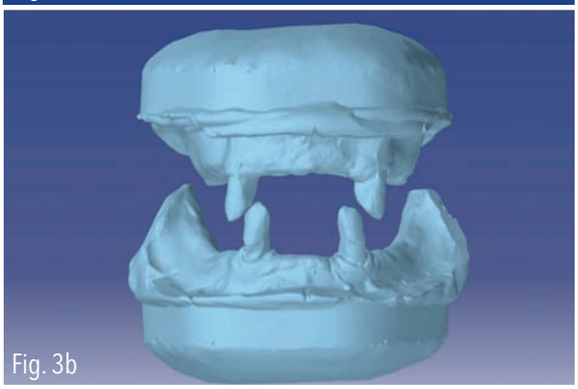


Fig. 3b


Fig.3c

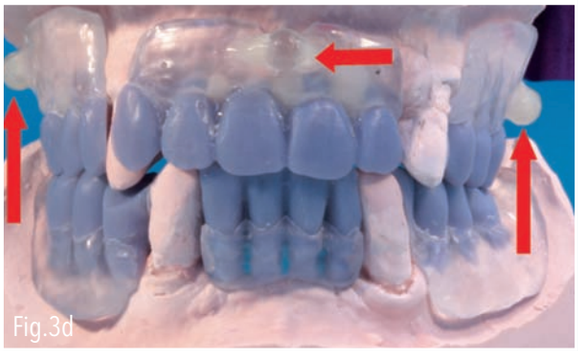


Fig.3d

Figs. 2a and 2b — Bone/muscle situation.

Figs. 3a to 3d — Digitalization of the models and X-ray template.

Nowadays, accurately designing and creating dental prostheses is much easier thanks to modern technology ranging from X-ray templates, drilling templates and immediate prostheses to the final restoration consisting of a chrome-cobalt structure with veneers. Aesthetic and functional harmony are the main focus during the design phase.

Software assistance

The patient is wearing a partial prosthesis with cuspid brackets (Fig. 1). We agree on a software-assisted restoration option to improve aesthetics and functional properties. In order to properly identify the bone and soft tissue ratio (Figs. 2a and 2b), we start by digitalizing the models (Figs. 3a and 3b) and create an X-ray template with a modified occlusal plane (position and size of the teeth) (Figs. 3c and 3d). The template has a radiopaque base (red arrows, Fig. 3d).

TAC Cone Beam

The TAC Cone Beam (Figs. 4a and 4b) visualizes soft tissue and cranial bones (Fig. 5). For an accurate positioning of the cranium, we use virtual reference points (Fig. 6):

Fig. 4a

Fig.4b

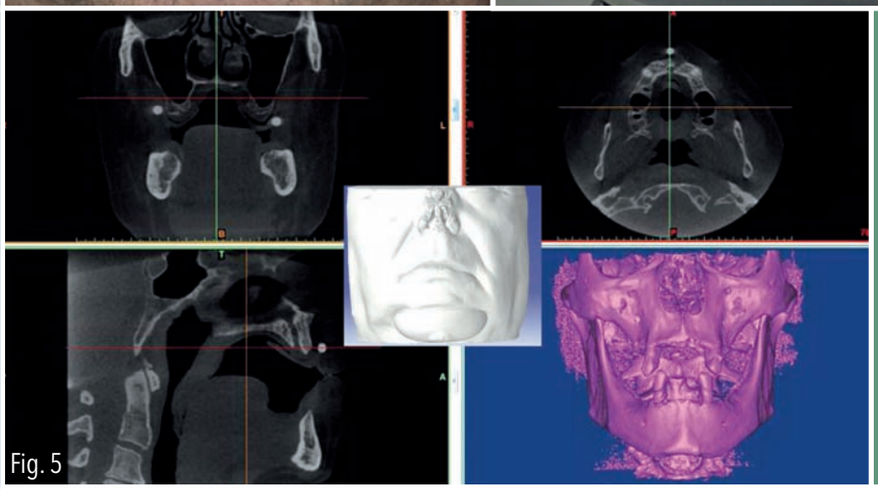


Fig. 5

Figs. 4a and 4b — Patient with an X-ray template. Measuring with the TAC Cone Beam.

Fig. 5 — Image of the hard and soft tissues.

Fig. 6 — Positioning of the cranium.

Fig. 7 — TAC and inserted models.

Fig. 8 — Camper's plane and bipupillary line for the occlusal plane.

Fig. 6

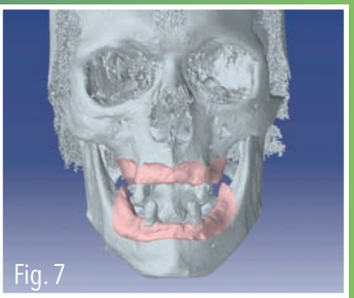


Fig. 7

Fig. 8

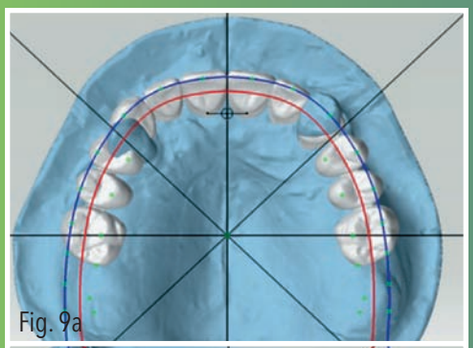


Fig. 9a

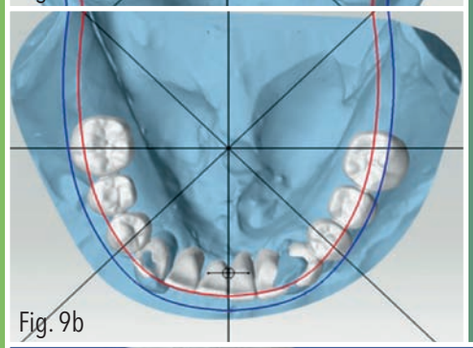


Fig. 9b

- The vertical plane: Tangent from the highest point of the crista galli (protuberance of the ethmoid bone) to the frontal nose spine;
- The sagittal plane: Tangent from the highest point of the crista galli to the centre of the sella turcica (part of the sphenoid bone); and
- The horizontal plane: Tangent (on both sides) from the lower edge of the eye sockets to the porion (highest point of the bony ear canal opening), also known as the "Frankfort Horizontal."

By simply importing the working models into the CAD program, we obtain bone structures with the previously digitized models (Fig. 7).

Drilling template

Visualizing the patient's real muscle-bone ratio allows us to evaluate various reference points necessary for determining the occlusal plane. For design of the temporary restoration, we use the Camper's line (the Camper's line lies between the tangents running from the nostril to the lower edge of the ear canal on each side of the face), with the bipupillary line serving as a reference point for the sagittal inclination angle of the frontal plane. This line runs parallel to the six front teeth and

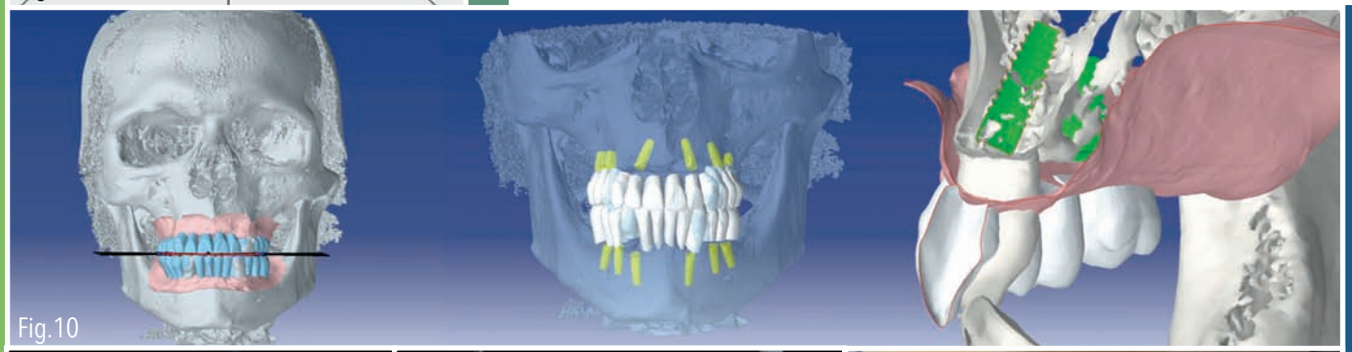


Fig.10


Fig. 11a


Fig. 11b


Fig. 11c


Fig. 11d

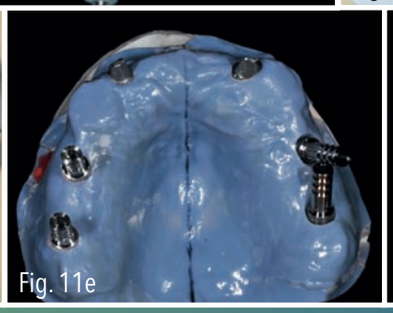


Fig. 11e

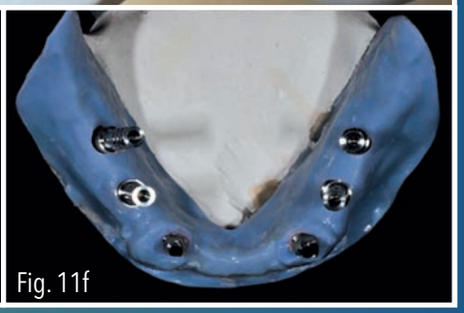


Fig. 11f

Figs. 9a and 9b — Biovolumetric template for planning the teeth's correct position and size.

Fig. 10 — Optimization with consideration of the present bone structure, implant and positioning of the teeth.

Figs. 11a to 11f — Drilling templates, temporaries and models with implants.

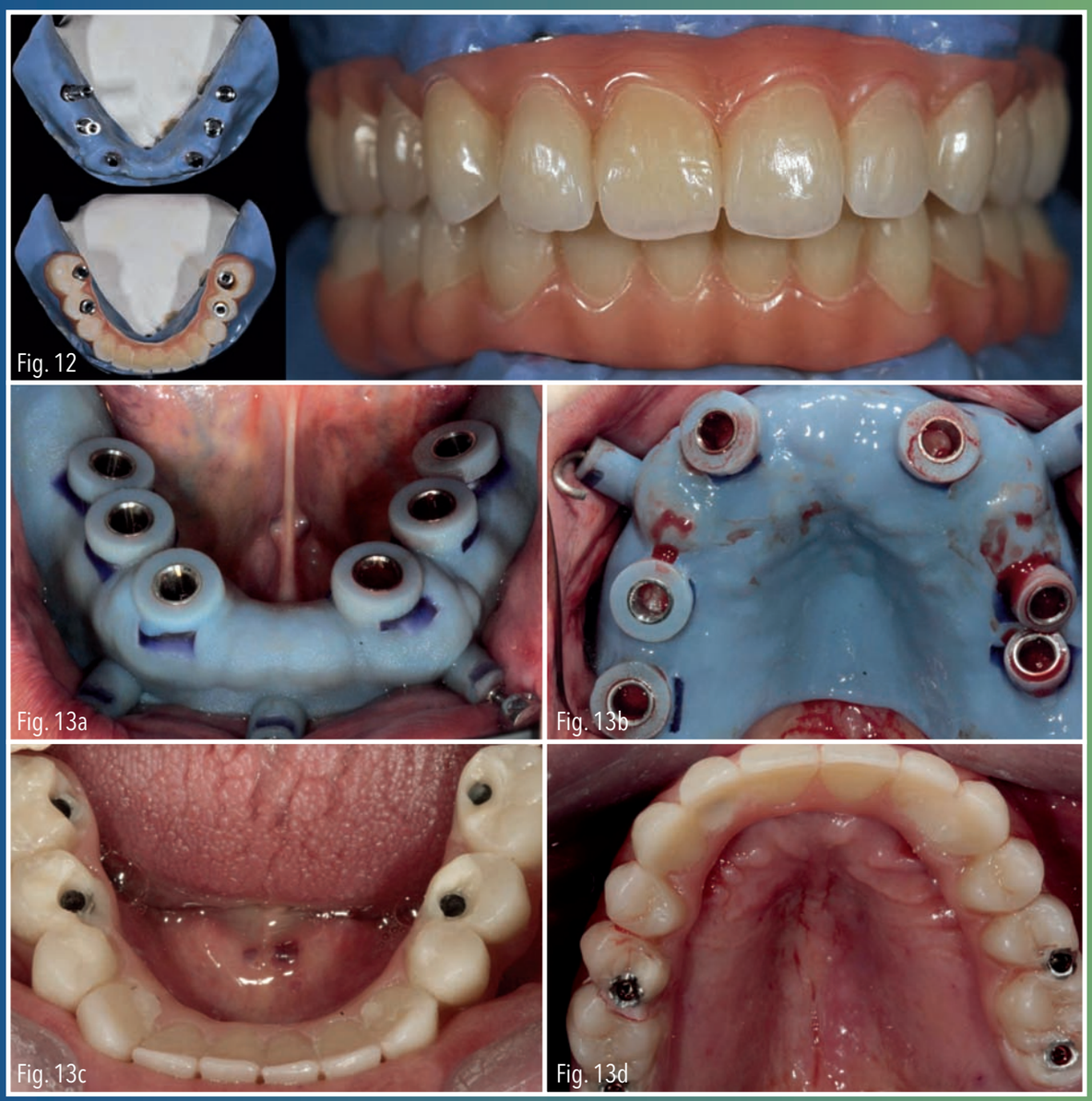


Fig. 12 — Temporaries with enamel, gingiva and guides.

Figs. 13a to 13d — Drilling template and fitting of the temporaries.

through the centres of the pupils (Fig. 8).

We now proceed by determining the size and positioning of the teeth with the help of biovolumetric templates (used for designing permanent restorations) (Figs. 9a and 9b). Determining the accurate bone amount and quality, the precise implant positions and proper positioning of the teeth is crucial in this planning phase (Fig. 10). The next step is the fabrication of drilling templates, temporaries and models with implant positions (Figs. 11a to 11f). The therapeutic temporary prostheses with gingiva and guides are ready to be placed on the models once the abutments have been properly integrated (Fig. 12).

Implantation and temporaries

Prior to inserting the implants and applying the therapeutic temporaries, we start with the positioning of the drilling templates (Figs. 13a to 14c).

This is a minimally invasive procedure with little or no bone structure damage and the patient receives a complete restoration the same day. After the implant sites have healed properly, the next step is the planning and construction phase for the permanent restoration.

Permanent prostheses

The CAD technique allows modification of previously designed work at any time. Individual harmony derives from aesthetics


Fig. 14a


Fig. 14b


Fig. 14c

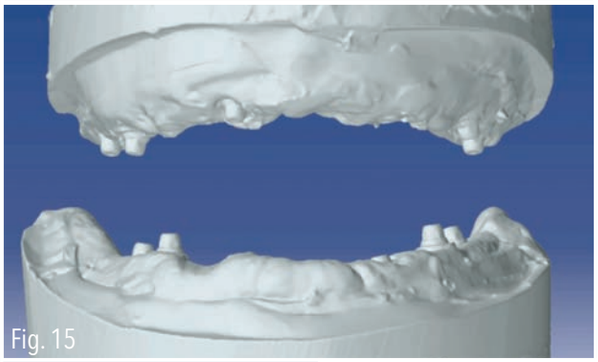


Fig. 15

Figs. 14a to 14c — Before and after the procedure.

Fig. 15 — Space condition.

Fig. 16 — Position of the teeth.

Fig. 17 — Dental arch shapes and matching facial shapes.

Fig. 18 — Arch/teeth dimension.

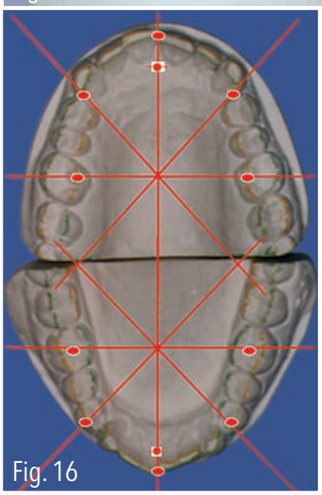


Fig. 16

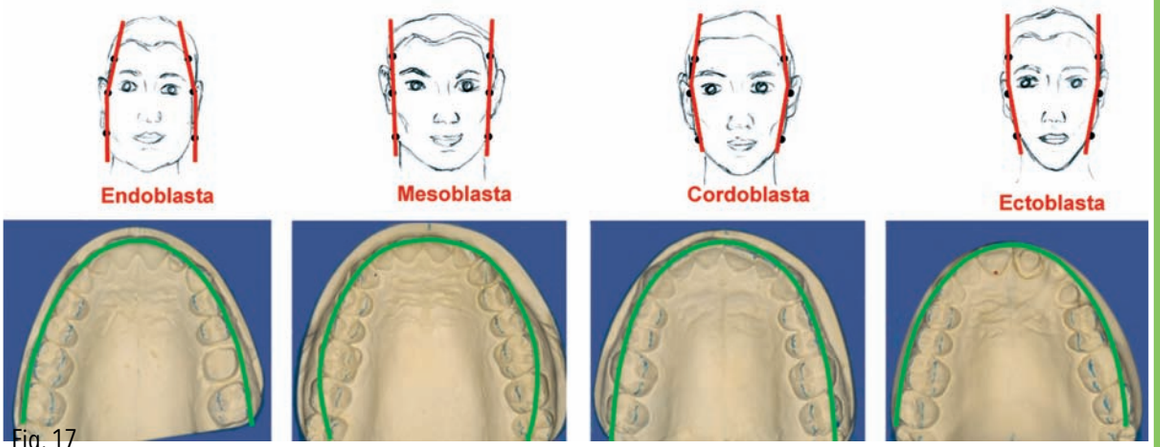
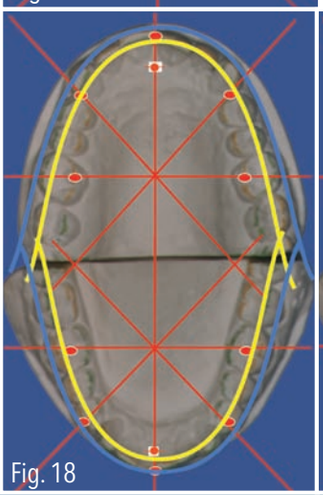


Fig. 17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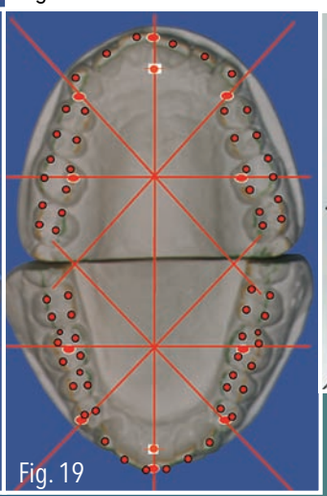


Fig. 19

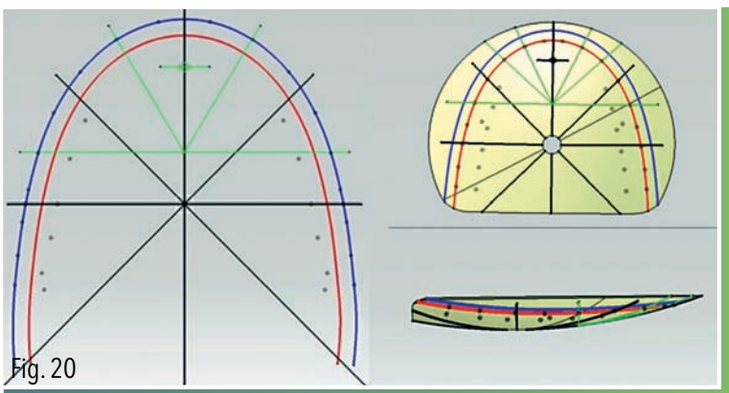


Fig. 20

Fig. 19 — Cusps/position ratio

Fig. 20 — Biovolumetric templates, upper plane and bottom calotte.

Fig. 21a

Fig. 21b

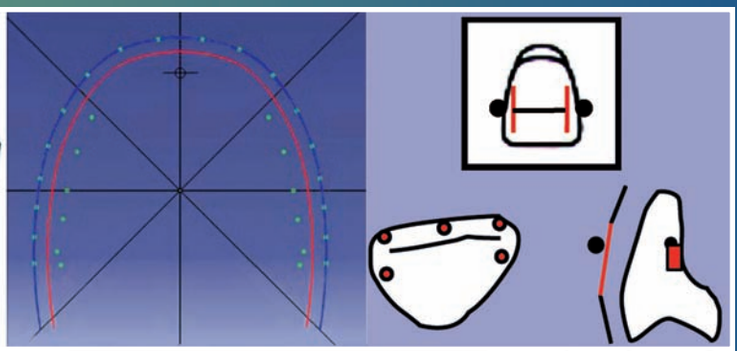


Fig. 21c

Fig. 21a — Face classification.

Fig. 21b — Facial shape for selecting the correct biovolumetric template and teeth.

Fig. 21c — Asymmetry of the face, tissue structures in the oral area for the set-up of the anterior teeth.

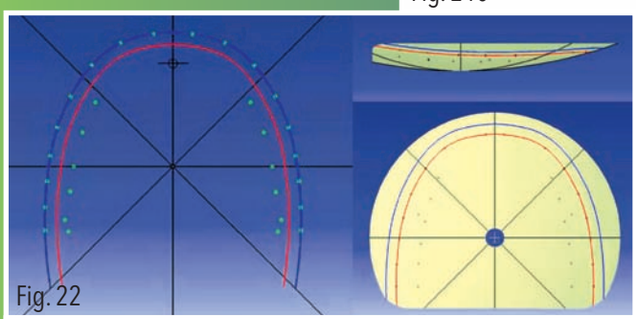


Fig. 22

Fig. 23

Fig. 24

Fig. 25

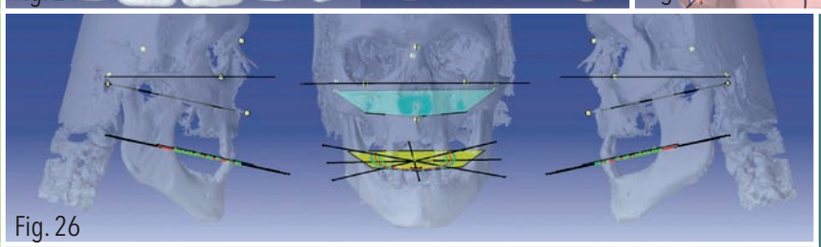


Fig. 26

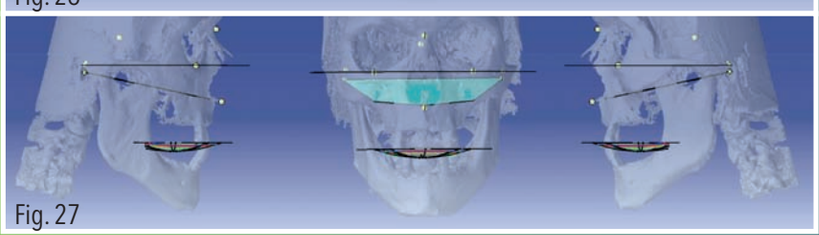


Fig. 27

Fig. 22 — Biovolumetric templates.

Fig. 23 — Fitting the biovolumetric template with the natural teeth.

Fig. 24 — Adjusting shape and size of the teeth.

Fig. 25 — Positioning of the templates in relation to the bone and muscle situation in the maxilla and mandible.

Fig. 26 — Camper's plane, reference point for the top template.

Fig. 27 — Frankfort Horizontal line, reference point for the bottom template.

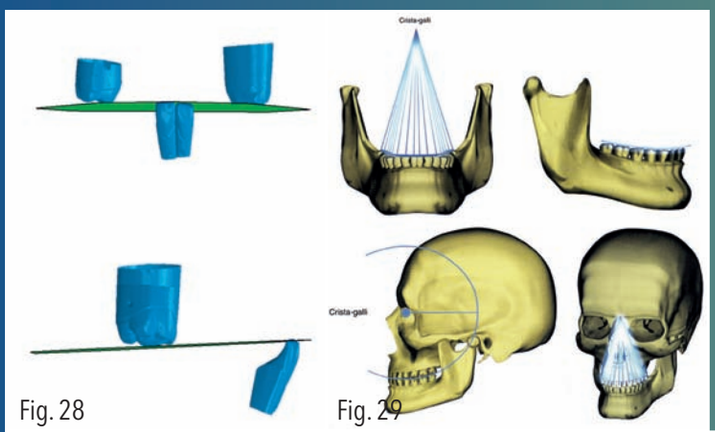


Fig. 28

Fig. 29

Fig. 28 — Reference planes.

Fig. 29 — Spee's curve, Wilson's curve and Crista Galli.

Figs. 30 and 31 — The finished design.

Fig. 32 — Adequate space for the design.

Fig. 33 — Reference points, proportions.

Fig. 34 — Base design.

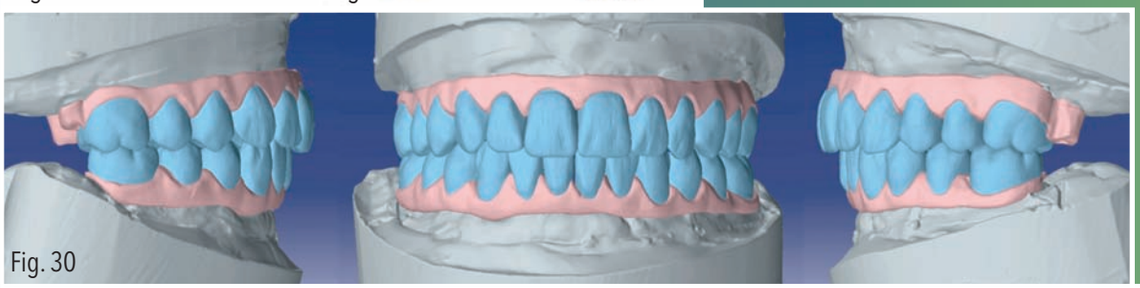


Fig. 30

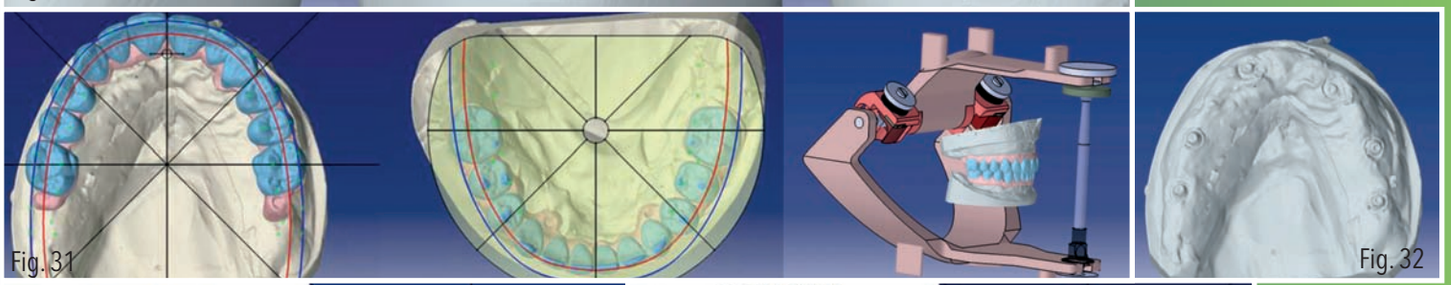


Fig. 31

Fig. 32

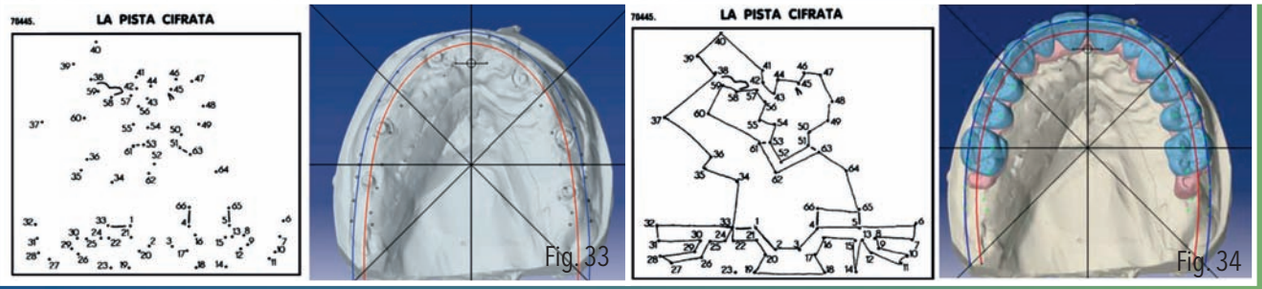


Fig. 33

Fig. 34

in combination with functional balance, such as chewing, swallowing and speaking. Adequate space is, therefore, an important factor (Fig. 15). Since different dental teams might work on the prosthesis' design and construction, for organizational purposes we arranged a standard series of instruments for the project (?). The biovolumetric templates were created because of the need to record codified working methods based on consistent measures and proportions.

Spacing conditions

In a physiological oral situation, certain areas of the teeth, marked with red dots in image 16, display a connection pattern. Images 17 and 18 show different shapes of tooth arches and teeth. The red dots connected by lines denote the teeth that will be preserved. We are also able to identify the individual cusps of the posterior teeth and the central growth cones of the anterior teeth (Fig. 19). Space varies, depending on the biotype and size of the individual tooth. The biovolumetric templates (Fig. 20) serve as organizational and structural tools. They enable us to systematically place the prostheses, thereby preventing unnecessary "empty" spaces.

Individualization

A facial analysis is useful for creating aesthetical and functional harmony. Face classification (Fig. 21a) determines biotype, asymmetry, typology and oral


Fig.35a


Fig.35b


Fig.35c


Fig.35d


Fig.36


Fig.37a

Fig.37b


Fig.37c

Figs. 35a to 35d — The prototype, reduced framework, in acrylic for the aesthetic evaluation.

Fig. 36 — Camper's plane and Frankfort Horizontal line/anterior aesthetics.

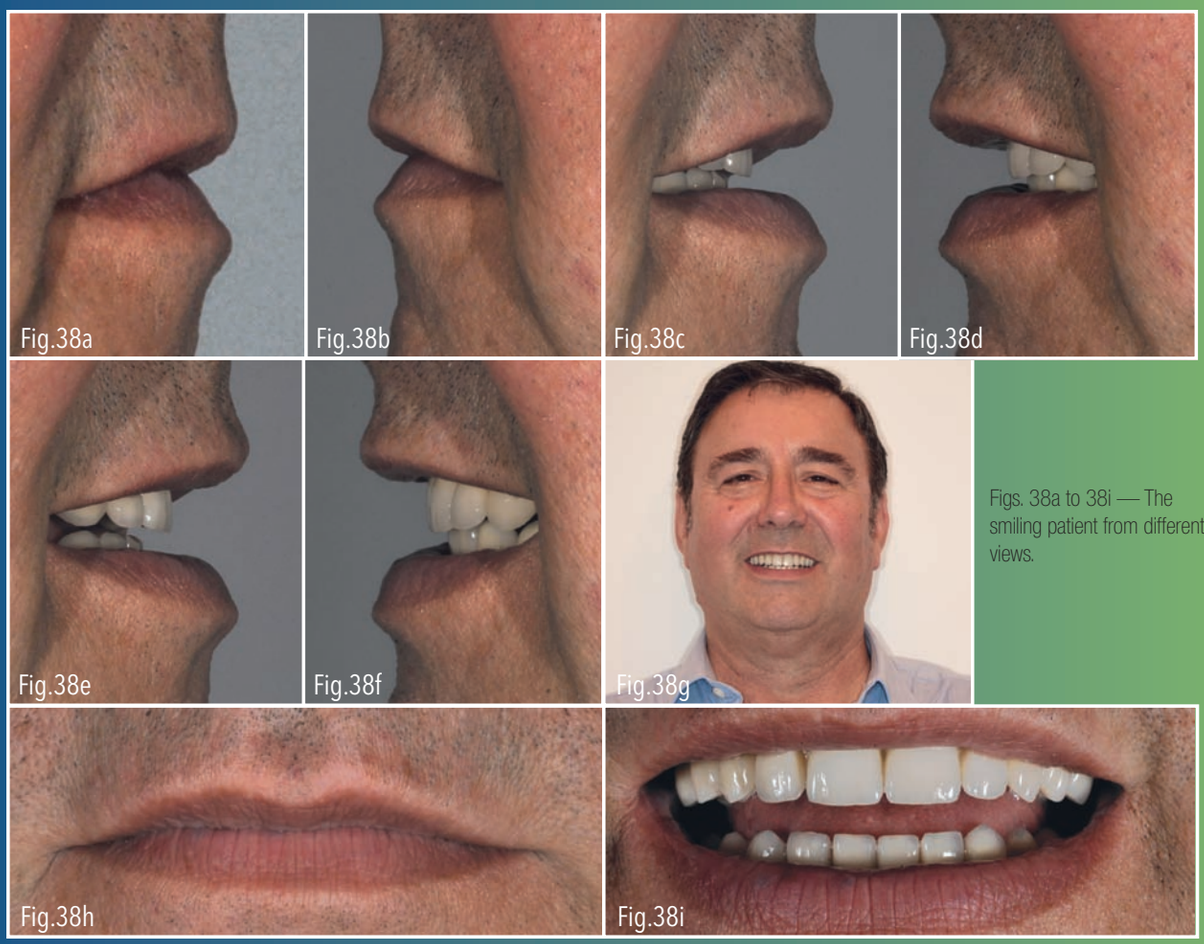
Figs. 37a to 37c — Finished prostheses.

tissue structures. I then select the proper biovolumetric template (Fig. 21b) and the matching tooth shape and continue by determining the Spee and Wilson curve, inclination angle, dominance, position and the anterior teeth set-up with the help of facial asymmetry and oral tissue structures.

Data maintenance

After the healing period, the next step is to digitalize the models of the temporary prosthesis and the new models with all available data (models, TAC etc). The following steps provide valuable information to identify or create available space:

- Tare the size of the biovolumetric template (Fig. 22) using the proportional code of the Wheeler chart in accordance with the preserved natural teeth (Fig. 23), thus generating an accurate template for the patient.
- Search the program for the correct teeth which fit the template in terms of size



Figs. 38a to 38i — The smiling patient from different views.

and shape (Fig. 24) and create permanent teeth for the patient.

- Position the templates for the occlusal plane in relation to maxilla and mandible using the available bone and muscle information (Fig. 25). The Camper's line (Fig. 26) and the Frankfort Horizontal line (Fig. 27) serve as reference points.

There is no occlusal plane per se, but rather an imaginary surface where the upper and lower teeth make contact. The occlusal plane is not a tangible element; it serves merely as a reference point during the design process. Determining a plane requires three reference points, but which points do we use?

During second dentition, the lower first molars and the lower incisors break through almost simultaneously and between these teeth lies the "occlusal plane." The two mesial-lingual cusps of the first upper molars serve as a reference point in the posterior area and the mesial-incisal point between the lower number ones (incisor point) are used for reference in the anterior area (Fig. 28). We now proceed by adding the following information:

- Integration of the Spee's and Wilson curve (Fig. 29), according to the face asymmetry;
- Dominance/set-up of the anterior teeth in relation to the oral area; and
- Completing the design process in the CAD software (Figs. 30 and 31).

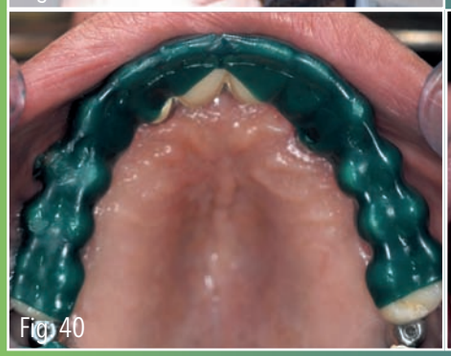
Advantages

Work procedures, reference points and proportions are integrated into the software easily and are accessible for any future rehabilitation work with similar characteristics. There is a difference between an empty piece of paper (Fig. 32) and a coded number puzzle (Fig. 33). By simply connecting the dots, we are able to create a basic drawing, but creating work with aesthetical and functional harmony for the patient depends mostly on the technician's skills.

Fig. 39 — Trial chewing with a banana.

Fig. 40 — Chewing and swallowing.

Fig. 41 — The myocentric.



Finishing

A prototype made of acrylic allows us to evaluate the aesthetics (Fig. 35a). After a try-in and necessary modifications, we move on to the planning and finishing of the framework (made of a chrome-cobalt alloy) for the permanent prosthesis (Fig. 35b). We fabricate another acrylic temporary prosthesis (Figs. 35c and 35d) prior to applying veneering to the framework. After firing, there is another try-in. Once the Camper's plane and aesthetics in the anterior region are verified (Fig. 36), the prostheses are ready for finishing (Figs. 37a to 37c).

Work assessment

Achieving aesthetic facial harmony depends on the interaction of various aspects which define facial expressions. Functional harmony is created by the proper interaction of prosthesis and muscles. The quality of the occlusal contacts which stabilize centric and impact dynamics is remarkable. The chewing cycle is the physiological component of functional harmony, demonstrated by the opening and closing movements during the masticatory process.

For the verification and evaluation of masticatory movements, chewing waxes made by Kerr and a banana are ideal. By simply placing chewing wax on the occlusal surfaces and letting the patient chew a piece of banana, we are able to evaluate the static and dynamics of the occlusal contacts at the same time (Fig. 39). The soft texture of the banana does not alternate the wax (Fig. 40). After verifying the masticatory process, we then test the habitual closing movement (Fig. 41). Verification of the quality of the occlusal contacts, according to the occlusal concept, is performed with occlusal paper.

Summary

Immediate prostheses:

- Digitalization of the initial situation;
- Planning and fabrication of the X-ray template on the TAC Cone Beam;
- Designing the drilling templates; and
- Positioning of the implants and insertion of the immediate prostheses.

Permanent prostheses (without TAC):

- Digitalization of the models after healing period and maxillomandibular relationship record;
- Collecting data for ensuring individual aesthetic and functional harmony;
- Creating biovolumetric templates;
- Individualizing aesthetic and functional harmony;
- Fabricating the prototype for aesthetic evaluation;
- Milling the framework and preparing it for veneering; and
- Applying aesthetic veneers to the framework.

Conclusion

Modern technology provides the necessary tools to preserve a patient's muscular and bone structures and, maybe eventually, their functional masticatory movements. Working with biovolumetric templates facilitates and speeds up the planning and production process, but the quality of the work depends on the technician's skills and experience. SD