

INDIVIDUALIZING ESTHETIC TREATMENT OUTCOMES: PLANNING AND FABRICATION



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Patients with failing or defective anterior restorations may lose the positional and anatomic features of the teeth and surrounding gingiva. When restoring the natural esthetics of a smile, the specific facial features and characteristics of each patient need to be taken into account. Generic smile design recipes¹⁻³ serve only as basic guidelines; they do not consider the individual and intrinsic tooth morphology and how it

relates to the facial features and characteristics of each patient.

Simply following a generic smile design recipe may lead to restorations that appear artificial and lack individuality. Optimal esthetic and functional results can be achieved only through a good knowledge of the natural anterior tooth morphology and by observing, analyzing, and modifying the provisional restorations over a period of time.

Recreating an esthetic smile in a patient with previous restorations will usually require two sets of provisional restorations. The primary provisional restorations are based on the existing restorations or a simple waxup, and are fitted on the day the teeth are prepared. The aim of this appointment is simply to remove the existing restorations and allow the patient to leave the office and continue his or her life as normal. Once the primary provisional restorations have been fitted, any adjunc-

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tive treatment, such as endodontic, periodontal, and/or implant treatment, can be carried out.

After the teeth are definitively prepared and the soft tissues are stable and disease free, an impression is taken of the prepared teeth to allow the definitive provisional restorations to be made in the laboratory. These definitive provisional restorations should be an esthetic and functional blueprint of the final restoration, and are based on information gathered from the primary provisional restorations as well as the definitive waxup. Fabricating the definitive provisional restorations on a cast of the actual tooth preparations has the following advantages:

- Additional space for acrylic resin allows for creation of ideal esthetic and functional form
- Additional bulk of material provides increased durability and strength
- Marginal accuracy of fit allows for good soft tissue response and biologic seal

The functional and esthetic characteristics of the definitive provisional restorations are then observed in the mouth, and if necessary, minor modifications can be made before proceeding with the final restorations.

The following case report illustrates the use of definitive provisional restorations and individualized tooth morphology to recreate a natural and esthetic smile.

CASE REPORT

The patient was a healthy, 38-year-old female (Fig 1) with two existing ceramic-fused-to-metal crowns on the maxillary central incisors. She had a cantilever resin-bonded prosthesis replacing the missing left canine and bonded to the first premolar (Figs 2 to 4). Her primary complaints were the unsightly appearance of the crowns, color mismatch of the pontic at the left canine site, and periodic debonding of the resin-bonded prosthesis.

An esthetic analysis of her smile revealed the following:

- Incorrect intradental proportion of the two anterior crowns
- Incorrect interdental proportion of the six anterior teeth
- Gingival margin disparity caused by recession above the left lateral incisor
- Flat smile line that did not follow the curvature of the lower lip
- Large interlabial space with a large lower lip and thin upper lip (Fig 5)

The treatment plan was as follows:

- Replacement of the existing crowns with all-ceramic crowns
- Placement of ceramic veneers on the lateral incisors
- Replacement of the resin-bonded prosthesis with a dental implant at the left canine site
- Connective tissue graft to improve the recession over the left lateral incisor

Placing the Initial Chairside Provisional Restorations

At the initial appointment, the primary provisional restorations were placed (Fig 6). Soon after, a dental implant was placed at the left canine site and a connective tissue graft was placed over the left lateral incisor and canine regions. The resin-bonded prosthesis was modified by drilling holes through the metal to create macromechanical retention, and then was used as the provisional restoration while the implant integrated.

The implant was exposed 4 months after placement and a healing cap was placed. By this time, the teeth were ready to receive the definitive provisional restorations. A shade was taken and a vinyl polysiloxane impression was made. At this stage, the lateral incisors were not yet prepared for ceramic veneers.

Fig 1 Preoperative facial view.

Fig 2 Preoperative right lateral view.

Fig 3 Preoperative anterior view.

Fig 4 Preoperative left lateral view.

Fig 5 Preoperative smile view.

Fig 6 Initial primary provisionals.



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Planning and Fabricating the Definitive Provisional Restorations: Laboratory Procedures

In the laboratory, the dental technician should receive the following from the clinician:

- Three casts showing the following information: (1) the original maxillary restorations, (2) the

mandibular arch, and (3) the initial treatment carried out by the clinician (ie, the gingival graft on the left lateral incisor, implant treatment at the left canine site, and the primary provisional restorations on the central incisors and left canine)

- Vinyl polysiloxane impression of the preparations of the central incisors and the implant at the left canine site (Fig 7)
- Facebow record



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Fig 7 Vinyl polysiloxane impression.

Fig 8 Implant cast fabricated in Metallepox epoxy resin. Note that in this stage, the trans mucosal zone is dictated by the shape of a stock implant impression post for a Replace Select regular platform 4.3-mm implant (Nobel Biocare).

- Implant impression post to be modified in the laboratory and given back to the clinician, who will use it to make the final impression
- Disk containing photographs of the patient's face and the initial treatment

An examination of the photographs of the patient's face revealed the following characteristics:

- The face had a rectangular/oval shape⁴
- The upper lip was thinner, indicating less support than the lower lip
- The smile was asymmetrical, because through habit, the patient opened the left side of the mouth to a greater extent, completely exposing the mandibular posterior teeth and gingiva
- The maxillary posterior teeth were below the plane of occlusion

The prescription from the clinician called for the fabrication of a diagnostic waxup, three provisional crowns on the central incisors and left canine, a gold interim implant abutment on the left canine, and two provisional veneers (before tooth preparation) on the lateral incisors.

The philosophy of excellence that underlies every laboratory stage performed by the author is naturally applied to the provisional restorations as well. The need for precision and accuracy is in no way different from that of the definitive restorations. The only difference between the two is the type of materials used.

The impression was disinfected⁵ and conditioned⁶ so that the impression material did not in-

teract negatively, from a chemical or physical standpoint, with the material used to make the implant cast (Fig 8).⁷ The removable dies on this cast were used to contour and fabricate the cervical third of the provisional crowns and to ensure a precise marginal fit with the aid of a microscope. After the implant cast was made, a solid cast was made from the same impression.

Both casts were fabricated using a special epoxy resin, *Metallepox* (product information available from author),⁷ which is more stable and durable than gypsum during all stages of the laboratory work.

The mandibular cast, which was made by the clinician, was finished to eliminate the bubbles and creases, and then retrimmed and squared to improve the orientation and make it more visually harmonious.⁸⁻¹⁰

Before mounting in the articulator, a manual control was performed using articulation film (Hanel, Langenau, Germany) to assess the maximum intercuspation between the maxillary and mandibular casts (Fig 9). Selective grinding was performed¹¹⁻¹⁹ to eliminate errors caused by the impression materials and stomatognathic system (dental intrusion, bone elasticity, meniscus compressibility, etc) (Fig 10).

With the help of a microscope, the exact position of each bite registration record made by the clinician was checked on the casts. The various casts were then cross-mounted on the articulator in all possible combinations that preserved the esthetic and functional information provided by the clinician.

Fig 9 Manual check of the maximum intercuspation using 12- μ m double-sided articulation film before mounting in the articulator.

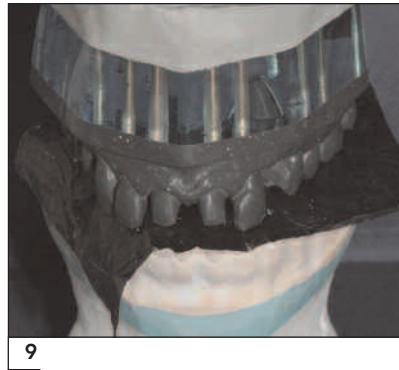


Fig 10 Distribution of occlusal contacts after the selective grinding was performed on the cast.

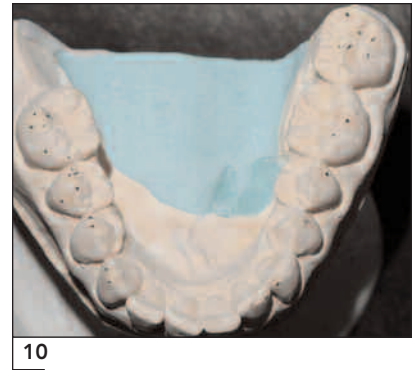


Fig 11 Waxup of the left canine. Note the difference in shape between the form of the cervical third of the crown and the circumference of the transmucosal zone as created by the stock impression post. (Photographed with a Zeiss OPMI 19-FC stereomicroscope [Zeiss, Thornwood, New York, USA]; magnification $\times 9$.)

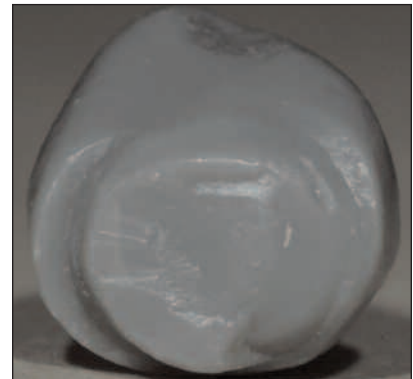
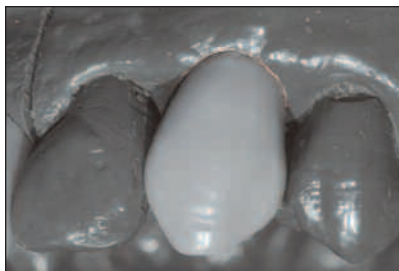
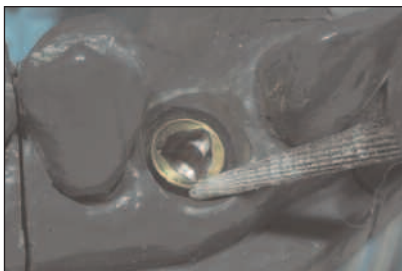


Fig 12 Transmucosal zone on the cast, shaped to develop the correct anatomy of the restoration.

Fig 13 Waxup of the left canine perfectly contained within the transmucosal zone of the properly shaped cast.

Fig 14 Reestablishment of correct proportion between the left lateral incisor and canine.

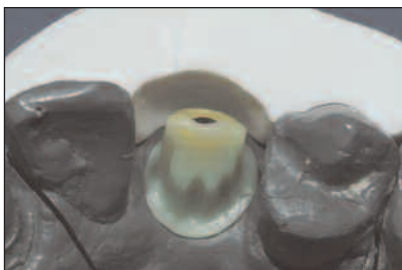


After mounting the casts, a removable waxup of the two central incisors and canine was fabricated. Two anomalies were evident:

1. An anatomic difference between the transmucosal zone and the cervical circumference of the left canine (Fig 11). To correct this, the form of the waxup of this tooth dictated the way in which the transmucosal zone of the cast must be modified for it to fit properly around the

perimeter of the crown. This allowed for support of the gingival tissue and conditioned it to take on the correct anatomy by shifting the free gingival tissue in the apical and buccal directions (Figs 12 and 13).

2. A lack of proportion between the anterior teeth. To reestablish a proper proportion, the distal side of the left lateral incisor required slight modification (Fig 14).



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Fig 15 Silicone mask used to evaluate the space needed for the fabrication of the telescopic abutment and the provisional for the left canine.

Fig 16 Separate implant analog with the "cast-to" abutment. The transmucosal zone was molded in wax and then relined in wax for additional precision. (Photographed with a Zeiss OPMI 19-FC stereomicroscope; magnification $\times 9$.)



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Fig 17 Casting in gold alloy. Note the cooling channels and the perfect bond between the alloy and the abutment. The melted alloy should not overflow onto the fitting surface of the abutment.

Fig 18 Refinishing, correction, and polishing of the transmucosal zone and fitting surface. (Photographed with a Zeiss OPMI 19-FC stereomicroscope; magnification $\times 9$.)

To allow for the proper geometric design of the implant telescopic abutment,⁷ a silicone mask was made on the waxup to evaluate the space taken up by the canine (Fig 15). The transmucosal area was then waxed on a "cast-to" abutment, which was finished later on a separate individual implant analog (Fig 16).

After casting the abutment with gold alloy (Silhouette 65 SF, Leach & Dillon, Cranston, RI, USA) (Fig 17), the telescopic abutment was fitted on a separate implant analog, off the cast. It was then refinished and polished in the transmucosal area (Fig 18) and fitted back on the cast. Next, the geometric design of the telescopic abutment was finalized via milling.

The implant antirotational and positional key⁷ was fabricated in heat-polymerizing acrylic resin. Its composition and the heating process were modified to produce more stability and rigidity.

The soft tissues around the end of preparation margins of the central incisors on the cast were removed with a bur, and white wax was used to eliminate all undercuts. The waxup was repositioned on the dies and a silicone impression was made to aid the fabrication of the provisionals.²⁰⁻²⁶

A thin spacer of wax was applied to the axial surfaces of the teeth and implant abutment to eliminate undercuts, provide space for the adhesive cement, and accommodate the polymerization shrinkage of the acrylic resin, which would impede the exact seating of the restorations. The acrylic resin for the provisionals was stratified and processed. The provisionals were then finished, perfecting their anatomy and refining the maximum intercuspal position and all possible protrusive and lateral excursions, until there was a smooth, harmonious movement, free of interference, on the articulator (Figs 19 to 21).²⁷⁻²⁹ Additional acrylic resin was added to the margin of the crowns to compensate for the contraction of the polymerized acrylic resin and to achieve perfect marginal closure.

On the cast, the two maxillary lateral incisors were slightly reduced, eliminating the resin composite placed in the mesial area by the clinician when the primary set of provisionals was made. This should be done only after completing the two central incisors and canine with the telescoping abutment, in order to preserve the spatial relationship between the teeth. Very little material was removed from the cast, because the lateral incisors



Fig 19 Refinement and careful evaluation of the functional aspects of the provisionals.



Fig 20 Refinished and polished palatal side of the provisionals on the gypsum cast with the gingival portion intact.



Fig 21 Refinished and polished labial side of the provisionals. Note the translucent acrylic resins, from pure to colored, at the middle third and interproximal areas, and the whitish enamel at the middle of the cervical third.



Fig 22 The definitive provisionals.



Fig 23 Interim telescopic abutment, electroplated in 99% gold. Note the highly polished transmucosal portion and the emergence profile relative to the fitting surface. The unusual, milled geometry and surface sanding improve adherence with the cement. (Photographed with a Zeiss OPMI 19-FC stereomicroscope; magnification $\times 6$.)

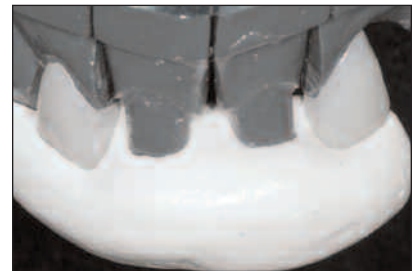


Fig 24 Gypsum key used to transfer the exact spatial position of the veneers to the oral cavity.

were built out labially in relation to the position of the central incisors and canine, so as to provide support for the upper lip and reduce the problem with the lower lip. The veneer facings were modeled in wax and then made entirely of enamel resin (Fig 22). The clinician then adapted them to the patient's teeth and relined them with a dentin resin of the same color used to make the provisionals for the central incisors and canine.

The axial part of the abutment and the interior portion of the provisionals were sandblasted to

improve their retention with the provisional adhesive cement. Gold plating of the telescopic abutment was carried out with 99% gold (Fig 23).

A special gypsum transfer and positioning key was made on the cast to allow the exact transfer of the position of the veneers to the oral cavity (Fig 24). These were relined in the mouth only after verifying that the gypsum key fit perfectly on the patient's teeth and that the veneers did not interfere with the preparations.



Fig 25 Impression post for the pickup technique with the transmucosal contour copied from the provisional abutment and crown worn by the patient for about 7 months. Note the design, which permits greater retention of the impression material. The buccal position, corresponding to the zenith of the gingival margin, is marked.

At this point, the transmucosal zone of the implant abutment was copied in acrylic resin on the implant impression post. This way, it could be used by the clinician to make the final impression (Fig 25).³⁰⁻³³ The gingival architecture determined by the cervical-transmucosal margin of the provisional crown and the canine abutment can be transferred onto the definitive cast when the final impression is made. The provisional abutment and crown should be worn by the patient for about 7 months before the clinician makes the final impression.^{34,35}

The implant impression tray was made of photopolymerizing resin composite.^{24,36-40} A hole was made for the pickup technique, along with occlusal stops and a midline marking for correct positioning inside the mouth. A honeycomb pattern of undercuts was placed on the internal surface to augment the adherence of the impression material.^{41,42} Before taking the impression, the clinician painted the impression post and tray with monomer and a bonding agent. When taking the impression, the clinician should unite the impression post and tray with a small amount of resin composite and then perform the photopolymerization (Fig 26). This procedure permits the preservation of the exact spatial positioning of the implant impression post with respect to the teeth, implant, and custom tray. In this way, when the laboratory analog is screwed on, there will be no movement of the impression post, and thus the



Fig 26 Implant tray. Note the portion of the impression post that protrudes through the tray and is connected by resin composite.

laboratory analog will accurately transfer the exact position of the implant from the patient's mouth to the final cast.⁷

The acrylic resin provisionals should be made anatomically correct, with a precise marginal fit and a perfect polish, performed with a microscope, to prevent the accumulation of bacterial plaque. In addition, before being sent to the clinician, the provisionals were exposed to a special conditioning treatment, called an *extreme purifying treatment*, which can be applied to all acrylic resins that will be inserted in the oral cavity. The stages of this treatment are as follows:

1. The acrylic resin is placed in a vacuum container for 30 minutes, with the vacuum pump working continuously and immersed in an ultrasonic bath at 132 kHz, at a temperature of 70°C.
2. Hydrogen peroxide (10.8%) is added, and the acrylic resin is left in the same container for another 60 minutes, with the vacuum pump still on and immersed in an ultrasonic bath at 132 kHz, at a temperature of 65°C.
3. The acrylic resin is left to rest in the same container, containing hydrogen peroxide (10.8%), for an additional 2 days.
4. The acrylic resin is placed in a glass container filled with purified, sterile water for 30 minutes, immersed in an ultrasonic bath at 132 Kh at room temperature.



Fig 27 Silicone matrix used as a preparation guide on the left lateral incisor.



Fig 28 Gypsum key for positioning the provisional veneer shells. Note the interim telescopic abutment in position.



Fig 29 Relining of the provisional veneer shells.

5. The glass container with the acrylic resin and water is placed in a microwave oven at 650 watts for 6 minutes. In case there are any residual metallic components, the prosthesis must first be dried and sealed in a paper/plastic sterilization pouch used for autoclaving instruments. This will prevent any metallic components from sparking and burning the acrylic resin.
6. The acrylic resin is allowed to rest for 2 days in purified, sterile water in the same container.

This treatment significantly reduces the cytotoxicity of the acrylic resins toward the soft and hard tissues^{43,44} due to the residual methylmethacrylate monomer and other filterable compounds eluted by the polymerization of the acrylic resin. It also results in an extremely efficient cleaning and disinfection of the acrylic resins,⁴⁵ improved mechanical properties,⁴⁶ and total saturation, meaning they will not absorb saliva or any other substance in the oral cavity.

After the extreme purification treatment, the acrylic resin prostheses were closed, without drying, in heat-sealed plastic bags to ensure their constant humidity and hygiene before being delivered to the clinician.

The clinician should receive the following from the dental technician:

- Gypsum key for the perfect alignment of the provisional veneers during relining
- Implant key for the exact placement of the telescopic abutment
- Modified impression post for the transfer of the exact morphology of the peri-implant tissues in the final impression to be used for the construction of the definitive restorations
- Provisional restorations for the assessment of osseointegration, function, and esthetics, and to shape the anatomy of the gingival tissues and permit the complete maturation of the peri-implant tissues

Placing the Definitive Provisional Restorations

The lateral incisors were prepared for ceramic veneers using silicone preparation guides based on the definitive provisional restorations (Fig 27).

The telescopic abutment was screwed into place using the implant jig,⁷ and the provisional veneer shells were relined with acrylic resin using the gypsum key (Figs 28 and 29).

The provisional restorations were cemented with non-eugenol-containing cements (TempBond NE and Tempbond Clear, Kerr, Orange, CA, USA) (Fig 30). Once cemented in place, a



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Fig 30 Completed provisional restorations.

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Fig 31 Smile view with provisional restorations in place.

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Fig 32 Facial view with provisional restorations in place.

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Fig 33 Preparations ready for the definitive impression.

small amount of acrylic resin was used to lute the provisional veneers to the adjacent provisional crowns on the palatal aspect. This mechanically locked the provisional veneers in place to increase their retention.

Minor modifications were made to the provisional restorations, and once the esthetic and functional aspects were approved by the patient, clinician, and dental technician (Figs 31 and 32), the final impression was made. The impression was made using a double retraction cord around the crowns and implant and single retraction cord around the veneer preparations (Fig 33). An implant impression tray was used for the implant impression.⁷ An impression was made of the

provisional restorations, and a maxillomandibular relationship record was made to allow cross-mounting of the cast of the provisional restorations with the cast of the preparations.

Planning and Fabricating the Definitive Restorations: Laboratory Procedures

At this stage, the clinician sent the following to the laboratory:

- Two casts: one of the definitive provisional restorations and one of the mandibular arch (the same used to build the definitive provisionals)

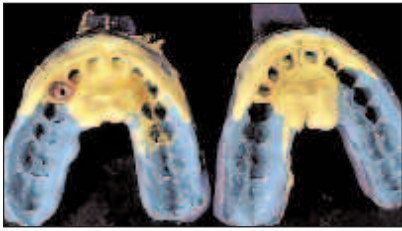


Fig 34 The two impressions received in the laboratory for construction of the definitive restorations.



Fig 35 Electroplated cast with Metallepox in the canine-to-canine region. After sectioning, only the two dies of the central incisors were used.

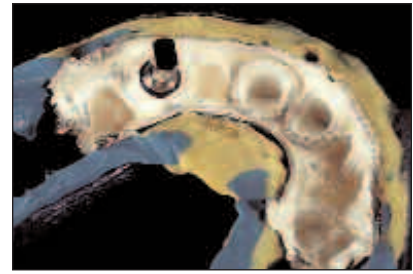


Fig 36 Electroplating of the impression from which the implant cast was developed. Note the electrodeposition around the implant analog, which exactly reproduces the transmucosal contour.



Fig 37 Implant analog embedded in epoxy resin contained in a festooned, truncated, conical excavation in a Plexiglas base (Degussa, Munich, Germany). In addition, this implant analog is held by pins for increased stability.



Fig 38 Labial side of the preparations on the implant cast.

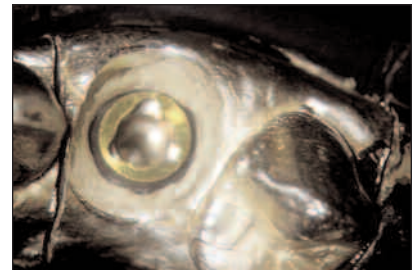


Fig 39 Implant analog in the working cast exactly reproduces the spatial position and geometric design of the implant head. The transmucosal area is created by the interim abutment and provisional crown.

- Two impressions (one had a marginal defect) in vinyl polysiloxane of the preparations of the incisors and the customized impression post on the left canine (Fig 34)

The prescription from the clinician requested the fabrication of the following:

- Three all-ceramic aluminum oxide crowns for the central incisors and left canine
- Two veneers in feldspathic ceramic for the lateral incisors
- An implant abutment in zirconium dioxide at the left canine

The impressions were disinfected,⁵ conditioned,⁶ and analyzed. Because of a marginal defect in the impression of the palatal aspect of the left central incisor, it was necessary to use both impressions

to make the definitive restorations. The accurate impression of the two central incisors was electroplated from canine to canine. Metallepox resin was then placed in the electroplated impression (Fig 35). The accurate impression of the lateral incisors and the implant was electroplated in the region between the first premolars. Metallepox resin was then placed in the electroplated and nonelectroplated parts of the impression, and an implant cast was fabricated (Fig 36).⁷ After polymerization was complete—which takes 48 hours for any epoxy resin, not 6 to 8 hours as claimed by various manufacturers—the implant cast was refinished only by eliminating the bubbles and the creases from the entire arch, without trimming the gingival tissue portion (Figs 37 to 39).

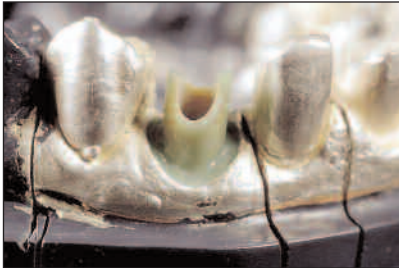
Before mounting the cast in the articulator, the maximum intercuspation between the maxillary and mandibular casts was checked manually using



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Fig 40 Detailed anatomic waxup of the definitive provisional is transferred onto the implant cast through cross mounting.

Fig 41 Waxup of the antirotational "cast-to" abutment for the definition of the geometric design of the telescopic abutment.



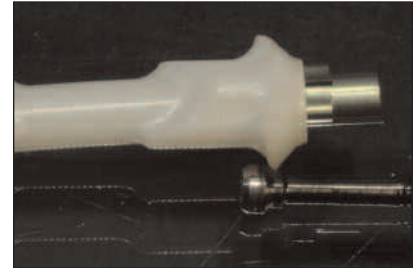
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Fig 42 Silicone mask made from the waxup showing the space available around the zirconium abutment for the definitive alumina crown. Note the geometric design of the milling.



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Fig 43 Densely sintered zirconia telescopic abutment.



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articulation film. With the use of a microscope, selective grinding was performed on the maxillary cast only, since the mandibular cast was the same one used for the fabrication of the definitive provisional restorations. The inclination of the condylar guidance of the articulator (Denar Mark II, Waterpik, Newport Beach, CA, USA) was set at 50 degrees. The various casts were cross-mounted, maintaining the esthetic-functional relationships established by the clinician. Next, the inclination of the condylar guidance was set at 25 degrees.

The electroplated dies, which were developed from the most precise and detailed impression of the two central incisors, were then sectioned and finished. These dies can be used to make the alumina copings and perfect the marginal closure. Later, the alumina copings were transferred and fit-

ted on the dies of the implant cast, using a microscope, to build up the ceramic crowns.

The entire gingival portion of the implant cast was left intact. On this cast, the teeth were waxed up (Fig 40), the crowns were built up with ceramic, and the final static and dynamic functioning check was performed using a microscope.

A silicone mask of the waxup was made to evaluate the space occupied by the canine and to allow the execution of the correct geometric design of the telescopic abutment (Figs 41 and 42).⁷ After scanning the implant abutment, the data were sent via modem to the Nobel Biocare production facility in Sweden, where the abutment was reproduced in zirconium dioxide modified with yttrium (Fig 43).⁴⁷⁻⁵⁰ The adaptation of the telescopic abutment was verified on a separate im-

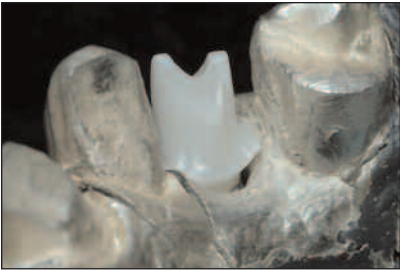


Fig 44 Telescopic abutment perfectly positioned on the implant analog in the cast, without interferences along the transmucosal contour.



Fig 45 Refining the milled geometric design using diamond-tipped burs and jets of water and air to prevent overheating, which could damage the abutment's structural integrity. (Photographed with a Zeiss OPMI 19-FC stereomicroscope; magnification $\times 6$.)



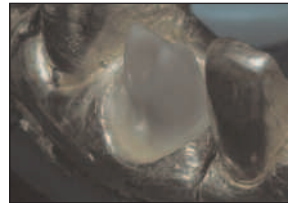
Fig 46 Portions of the abutment shoulder in the transmucosal zone not manufactured by the CAD/CAM system because the angle of emergence of the transmucosal portion of the abutment is greater than 30 degrees.



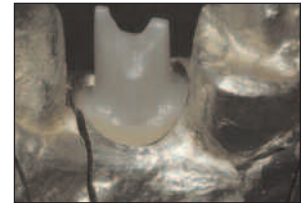
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Fig 47 Portions of the shoulder in the transmucosal zone rebuilt using the compatible laminating zirconia shoulder ceramic. Note the finish and polish of the ceramic, which promotes integration with the surrounding tissues. The abutment is manufactured to fit on an externally hexed implant. A titanium antirotational element is then attached to the abutment and converts the external connection into an internal connection. (Photographed with a Zeiss OPMI 19-FC stereomicroscope; magnification $\times 9$.)

Fig 48 Geometric design of the axial portion and the emergence profile of the transmucosal portion of the telescopic abutment. (Photographed with a Zeiss OPMI 19-FC stereomicroscope; magnification $\times 6$.)

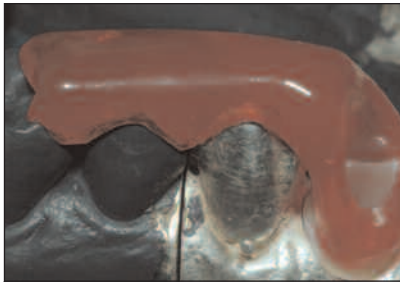
Fig 49 Intracrevicular positioning in the labial area of the margin of the telescopic abutment.

Fig 50 Equigingival positioning of the palatal and interproximal margins of the telescopic abutment.

plant laboratory analog. It was then transferred to the cast and finished with rubber points until it fit perfectly on the separate implant analog and transmucosal area of the cast (Fig 44). Only then can the geometric design of the telescopic abutment be milled using diamond-tipped burs⁵¹ and water (Fig 45). Some areas of the transmucosal zone could not be produced by the CAD/CAM Procera system (Nobel Biocare, Göteborg, Sweden) because it cannot reproduce angles of more

than 30 degrees. Instead, these areas were produced by hand using a specific ceramic for zirconium (Fig 46). After sandblasting and applying the bonding agent to the abutment, the modified shoulder ceramic was added and fired. The shoulder ceramic was refined and perfectly adapted to the transmucosal zone of the implant cast. It was then polished and fired for autoglazing (Figs 47 to 50).

The implant antirotational transfer and positioning key⁷ was made using heat-hardening acrylic



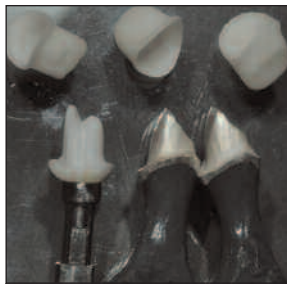
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Fig 51 Implant jig, which permits the exact transfer and positioning of the telescopic abutments from the working cast to the oral cavity and vice versa.

Fig 52 Duplicate dies of the lateral incisors made in refractory material.



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Fig 53 Densely sintered aluminum oxide copings (top). Implant abutments in densely sintered zirconia (bottom).

Fig 54 Surface of the copings treated to receive the ceramic. Note the marginal reduction to allow a sufficient quantity of translucent orange and fluorescent ceramic to be applied.

resin with a modified composition and heating modality to make it more stable and rigid (Fig 51).

Scans of the central incisors and left canine were sent to the Nobel Biocare production facility, which produced three copings in aluminum oxide.

Duplicate dies of the lateral incisors were made in refractory material and used to make the veneers. The refractory material was degassed by heating it in a vacuum at 1,000°C for 11 minutes. The dies were then held in normal atmospheric pressure at 1,052°C for 7 minutes (Fig 52). The T-Glass feldspathic ceramic (Vintage Halo, Shofu, San Marcos, CA, USA) was applied and heated at 1,000°C for 2 minutes. The waxups of the central incisor and left canine crowns were replaced on their respective dies to provide reference points and aid in the fabrication of the veneers. The intensified dentinal and translucent ceramics were layered and heated at 940°C for 1 minute. The various enamels were heated at 930°C for 1 minute. An additional heating was done for autoglazing, which included some additional ceramics and stains, at 920°C for 1 minute. Finally, the veneers were refined.

To match the color of the cervical zone of the natural teeth, the entire margin of the Procera copings was reduced horizontally by 0.2 to 0.4

mm (Figs 53 and 54). The copings were fitted not only on the segmented dies, but also on the dies of the implant cast, where the ceramic layering was performed later. The copings were treated with diamond-tipped ceramic burs and sanded with highly pure, reddish-brown, 50- μ m aluminum oxide from Brazil (Perio-R-Blast, Talladium, Valencia, CA, USA) at 2.5 atm. They were then placed in a container with carbon tetrachloride and immersed in an ultrasonic bath at 80°C for 5 minutes, followed by steam cleaning and boiling in purified water for 10 minutes in a ceramic pan.

The all-ceramic crowns for the central incisors and left canine were then fabricated via layering with Nobel Rondo Alumina ceramic (Nobel Biocare). First, an initial application of the shoulder ceramic was made and fired, followed by a second application and corrective firing (Fig 55). Next, the dentinal ceramics were applied, with intense chroma (chromatizer) at high values, along with the translucent ceramics, from clear to colored, to create a very irregular and uneven surface (Fig 56). This distributes the light inside the restorations, as in natural teeth. The alternation of the various ceramics and the absorption, reflection, and refraction of the diffused light, allow the light to circulate

Fig 55 All-ceramic crown after firing of the shoulder ceramic. Note the degree of precision achieved at this stage. (Photographed with a Zeiss OPMI 19-FC stereomicroscope; magnification $\times 6$.)



Fig 56 Application of dental and translucent ceramics, from pure to colored, forming an irregular and uneven surface that will react positively to light. (Photographed with a Zeiss OPMI 19-FC stereomicroscope; magnification $\times 6$.)

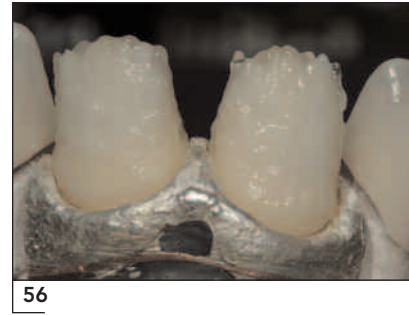
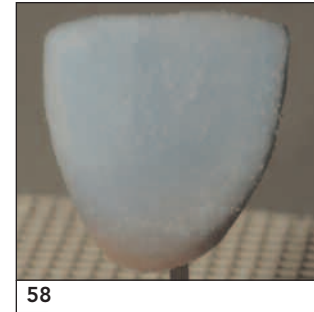


Fig 57 Layering of the dental ceramics and dental cuts.



Fig 58 Packed and condensed ceramics⁵² of the left central incisor before sintering.



inside the restorations, thanks in part to the irregularity and unevenness of the layers of ceramic. This creates a live, natural appearance for the prosthetic teeth. In the same way, the dentin of the teeth was stratified, and a dentinal cut was made for the application of the successive ceramic, based on the color stratification found in the natural teeth (Fig 57). The translucent ceramics were applied, from clear to colored, depending on the values found in the natural teeth, followed by the various enamels, alternated with the opalescent and fluorescent ceramics in both vertical and horizontal layers with the mother-of-pearl modifiers. The teeth were made with a slightly larger total volume to (1) eliminate the effect of the contraction of the ceramic when fired; (2) define the anatomy of the teeth by firing the dentin and enamel only once and using only the nucleus of the ceramic, which offers superior quality; and (3) finish the teeth with just three firings, including the autoglaze, stains, and final corrections of the shoulder ceramic (Fig 58).

This way, the physical properties of the ceramics remain unaltered and the restorations have a more natural look, because the various ceramic layers have been sintered, not vitrified, and are

less stressed because they have been fired fewer times. In fact, the more ceramic is fired, the more its coefficients of thermal expansion and contraction will vary.⁵² This can generate radial tension instead of radial compression, which can lead to failure. In addition, a limited number of firings will help produce an optimal match between the restoration and the patient's natural teeth in terms of opalescence, iridescence, and fluorescence.

Finally, the ceramic teeth were refinished, defined, and polished using specific rubber tips (Fig 59).

At this point, the clinician should schedule an appointment for a trial fitting of the restorations before they are completed to assess the precision (Figs 60 and 61), function (Fig 62), physiology (Figs 63 and 64), and esthetics (Figs 65 to 68).

In order to achieve excellent results, each prosthesis must be unique, just like the individual who will wear it. There are no hard and fast rules for making restorations that have a truly natural appearance. Knowledge, skill, experience, and the ability to relate to others must combine synergistically to produce the optimal outcome. To this end, the clinician and the dental technician must scrupulously collect all the data, along with the expectations of the patient, so that they can work



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Fig 59 Physiology and functional anatomy of the definitive restorations, created with carbon-silicon and diamond-tipped burs on a water turbine and abrasive and polishing rubber tips on an electric handpiece.

Fig 60 Finished canine. Note the precision of the margin and the continuity between the contour of the crown and the transmucosal contour of the abutment. (Photographed with a Zeiss OPMI 19-FC stereomicroscope; magnification $\times 9$.)

Fig 61 Distal view of the right central incisor. Note the anatomy of the labial and palatal contours of the crown, the gradual inclination of the functional area, and the precision of the margin. It was decided to eliminate the ceramic in the two areas of the preparation margin where there were imperfections, because they might have damaged the ceramic during cementation. (Photographed with a Zeiss OPMI 19-FC stereomicroscope; magnification $\times 6$.)

Fig 62 Palatal view of the central incisors showing the perfectly polished functional surface. The margins of the two crowns were closed perfectly on the individual dies and then transferred and fitted to the dies of the implant cast with the aid of a microscope, in order to perform an accurate static and dynamic functioning check. (Photographed with a Zeiss OPMI 19-FC stereomicroscope; magnification $\times 9$.)

Fig 63 Distal portion of the left central incisor. Note (1) the perfectly polished, extremely compact surface, which is easier for the patient to keep clean; (2) the three-dimensional anatomy of the incisopalatal and incisolabial thirds, which characterize and personalize the tooth; (3) the gradual inclination of the functional area, which ensures freedom of movement and comfort; and (4) the special shape of the distal side, from the middle third to the cervical third, with the excess ceramic used to close the papillary space.

Fig 64 Contour and labial surface of the restorations of the right lateral incisor and central incisors.

together to realize a custom-designed prosthetic device—perfect in anatomy, function, precision, and esthetics—that reflects the personality of the patient⁵³ and is perfectly integrated over the long term in the biologic environment of the oral cavity.

Cementing the Definitive Restorations

Once the definitive restorations were completed, the provisional restorations were removed. After removing the interim telescopic abutment,⁷ it was ev-

Fig 65 Labial view of right lateral and central incisors.



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Fig 66 The definitive restorations.



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Fig 67 Labial view of left central incisor, lateral incisor, and canine. Note the harmonious relationship between the shapes and the precise polishing of the cervical surface of the ceramic, which reflects the electroplated areas of the cast.



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Fig 68 Along with the definitive restorations and implant jig, the clinician should receive a new abutment screw and a locking, antirotational, titanium insert to connect the zirconium abutment to the implant. These have never been subjected to stress and are used only for the final attachment of the zirconium telescopic abutment.



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Fig 69 Implant and peri-implant tissues of the left canine. The tissues have perfectly matured around the contour of the crown and interim abutment. The tissues did not collapse, despite the removal of the provisional crown and the interim telescopic abutment.

Fig 70 Telescopic abutment in zirconium being attached to the implant head. The implant jig accurately engages the specific geometric profile of the telescopic abutment, allowing for exact positional transfer from the cast to the mouth. The jig also provides resistance to rotation and acts as a countertorque when fastening the screw.

Fig 71 Cementation of the ceramic veneer under rubber dam.

ident that the transmucosal zone had been properly modified and was now healthy and mature (Fig 69). The definitive zirconium telescopic abutment was torqued into place with the implant jig (Fig 70).⁷ The jig accurately engaged the specific geometric profile of the abutment, thereby creating resistance to rotation and acting as a countertorque.

The two ceramic veneers were cemented under rubber dam using a light-cured resin cement (Rely

X veneer cement, 3M ESPE, St Paul, MN, USA) (Fig 71). The three aluminium oxide crowns (Procera, Nobel Biocare) were cemented into place with a chemically cured resin cement (Panavia 21, Kuraray, Osaka, Japan).

Comparing the before and after photographs shows the importance of individualizing the tooth morphology according to the patient's unique facial features (Figs 72 to 81).



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Fig 72 Left dentofacial view 1 week after cementation. Note the presence of a perspective progression, natural appearance of the incisal embrasures, specific anatomic character of each tooth, and improved relationship between the restorations and the lower lip.

Fig 73 A satisfied smile 1 week after cementation. Note the individual nature of the single restorations and their harmonious relationship to the facial composition.



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Fig 74 Right dentofacial view 1 month after cementation. Note the altered form of the lips caused by the reestablishment of natural support from the teeth, the improvement of the teeth-lips relationship, and the specific individual dominance of each tooth.

Fig 75 Frontal dentofacial view 1 month after cementation. Dominance of the individual teeth is an indispensable element in achieving a harmonious dentofacial composition.

Fig 76 Right occlusal view 1 month after cementation. The tissues around the restorations of lateral incisor and central incisors are beginning to recover their physiologic equilibrium. Note the anatomic details, such as the angular-axial transition lines, surface texture, and three-dimensional anatomy of the incisopalatal third and incisolabial third, which characterize and personalize the teeth. The contour of the crowns was shifted labially to stimulate and support the lips, and is in harmony with the gingival contour.

Fig 77 Frontal occlusal view. Note the radiant symmetry produced by the balance between the forces of separation and forces of cohesion, which give dynamism and vitality to the dental composition. Also note the dynamism of the light generated by the contrast between the various colors, between the opacity and translucence, and between the lines and structures, which combine to produce a pleasant visual effect.

Fig 78 Left occlusal view 1 month after cementation. The tissues around the restoration of the canine are reacting to the stimulus provided by the correct anatomy of the coronal and transmucosal contours.

Fig 79 Frontal dentofacial view 7 months after cementation. The curvature of the lower lip follows the arc of the maxillary teeth, and the smile has a defined, balanced appearance.

Fig 80 Left dentofacial view 8 months after cementation. The tissues around the restorations of the central incisors and left lateral incisor and canine continue to adapt and integrate with the restorations. Note that the papilla between the left central and lateral incisors has occupied most of the physiologic space available.

Fig 81 Before beginning the esthetic treatment, the patient was dissatisfied and discouraged by the unnatural appearance of her prosthesis (see Fig 1). Eight months after the insertion of the definitive restorations, the patient is relaxed and confident.



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CONCLUSIONS

Every face has individual features and characteristics, and this individuality should be imparted to the restorations and smile design. Applying generic smile design recipes without understanding and modifying the unique tooth morphology will create characterless and unnatural restorations. In cases such as the one presented in this article, the clinician can be easily misled into thinking that the treatment will be simple and can be completed in a short period of time. However, because of the patient's specific features, generically shaped teeth would have yielded a compromised result. Only through a continuous dialogue between the clinician, dental technician, and patient, and by properly evaluating and modifying the provisional restorations, can excellent, individualized results be achieved.

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REFERENCES

- Magne P, Belser U. Bonded Porcelain Restorations in the Anterior Dentition: A Biomimetic Approach. Chicago: Quintessence, 2002.
- Chiche GJ, Pinault A. Esthetics of Anterior Fixed Prosthodontics. Chicago: Quintessence, 1994.
- Scharer P, Rinn LA, Kopp FR. Aesthetic Guidelines for Restorative Dentistry. Chicago: Quintessence, 1982.
- Caradonna C, Caruso C, Lotti M. Ortognatodonzia come arte. Ortognatodonzia Italiana 1998;7:69–96.
- Owen CP, Goolam R. Disinfection of impression materials to prevent viral cross contamination: A review and a protocol. Int J Prosthodont 1993;6:480–494.
- Sgrò S, Eliseo M. Galvanoplastica in argento. Ottimizzazione del metodo. Dental Labor 1998;5:449–456.
- Sgrò S. Accurate positional impression, accurate positional cast, and antirotational transfer and positioning key in the fabrication of implant-supported prostheses. Quintessence Dent Technol 2005;28:27–48.
- Pedroli G. Il modello di studio ortodontico. La Quintessenza Odontotecnica 1992;4:383–394.
- Köhler H. Utilizzo della dima angolare di Leleux secondo Köhler e Döring. La Quintessenza Odontotecnica 1994;8:783–793.
- Yamamoto M, Miyoshi Y, Kataoka S. Basi fondamentali di estetica: Tecniche di modellazione per i restauri metallo-ceramici. Quintessenza Odontotecnica 1991;15:10–81.
- Boyarsky HP, Loos LG, Leknius C. Occlusal refinement of mounted casts before crown fabrication to decrease clinical time required to adjust occlusion. J Prosthet Dent 1999;82:591–594.
- Loos LG, Boyarsky HP, Quiring DJ. Procedure for occlusal refinement of mounted definitive casts to reduce clinical time required for adjustment of occlusion. J Prosthet Dent 2001;85:246–251.
- Carossa S, Lojacono A, Schierano G, Pera P. Evaluation of occlusal contacts in the dental laboratory: Influence of strip thickness and operator experience. Int J Prosthodont. 2000;13:201–204.
- DeLong R, Ko CC, Anderson GC, Hodges JS, Douglas WH. Comparing maximum intercusp contact of virtual dental patients and mounted dental casts. J Prosthet Dent 2002;88:622–630.
- Davies S, Al-Ani Z, Jeremiah H, Winston D, Smith P. Reliability of recording static and dynamic occlusal contact marks using transparent acetate sheet. J Prosthet Dent 2005;94:458–461.
- Millstein P, Maya A. An evaluation of occlusal contact marking indicators. A descriptive quantitative method. J Am Dent Assoc 2001;132:1280–1286.
- Schelb E, Kaiser DA, Bruckl CE. Thickness and marking characteristics of occlusal registration strips. J Prosthet Dent 1985;54:122–126.
- Proschel PA, Maul T, Morneburg T. Predicted incidence of excursive occlusal errors in common modes of articulator adjustment. Int J Prosthodont 2000;13:303–310.
- Morneburg TR, Proschel PA. Predicted incidence of occlusal errors in centric closing around arbitrary axes. Int J Prosthodont 2002;15:358–364.
- Wang RL, Moore BK, Goodacre CJ, Swartz ML, Andres CJ. A comparison of resins for fabricating provisional fixed restorations. Int J Prosthodont 1989;2:173–184.
- Mojon P, Oberholzer JP, Meyer JM, Belser UC. Polymerization shrinkage of index and pattern acrylic resins. J Prosthet Dent 1990;64:684–688.
- Ness EM, Nicholls JI, Rubenstein JE, Smith DE. Accuracy of the acrylic resin pattern for the implant-retained prosthesis. Int J Prosthodont 1992;5:542–549.
- Moulding MB, Loney RW, Ritsco RG. Marginal accuracy of indirect provisional restorations fabricated on polyvinyl siloxane models. Int J Prosthodont 1994;7:554–548.
- Takahashi J, Kitahara K, Teraoka F, Kubo F. Resin pattern material with low polymerization shrinkage. Int J Prosthodont 1999;12:325–329.
- Burns DR, Beck DA, Nelson SK. A review of selected dental literature on contemporary provisional fixed prosthodontic treatment: Report of the Committee on Research in Fixed Prosthodontics of the Academy of Fixed Prosthodontics. J Prosthet Dent 2003;90:474–497.
- Nejatidanesh F, Lotfi HR, Savabi O. Marginal accuracy of interim restorations fabricated from four interim autopolymerizing resins. J Prosthet Dent 2006;95:364–367.

27. Sato Y, Koretake K, Hosokawa R. An alternative procedure for discrimination of contacts in centric occlusion and lateral excursion. *J Prosthet Dent* 2002;88:644–645.
28. Harper KA, Setchell DJ. The use of shimstock to assess occlusal contacts: A laboratory study. *Int J Prosthodont* 2002;15:347–352.
29. Noveri F. *Elementi Storici Critici Filosofici Pratici di Gnatologia*. Milan: Edi-Ermes, 1982.
30. Bruni A, Luzit R. Maggiore estetica nel settore cervicale. L'impianto-abutment individuale. *Dental Labor* 1998;1:19–29.
31. Hinds KF. Custom impression coping for an exact registration of the healed tissue in the esthetic implant restoration. *Int J Periodontics Restorative Dent* 1997;17:584–591.
32. Hochwald DA. Surgical template impression during stage 1 surgery for fabrication of a provisional restoration to be placed at stage 2 surgery. *J Prosthet Dent* 1991;66:796–798.
33. Dieterich J. Corona naturescente su monoimpianto con *emergence profile*. *Dental Dialogue* 2002;6:640–647.
34. Bengazi F, Wennstrom JL, Lekholm U. Recession of the soft tissue margin at oral implants: A 2-year longitudinal prospective study. *Clin Oral Implants Res* 1996;7:303–310.
35. Ekfeldt A, Eriksson A, Johansson LA. Peri-implant mucosal level on patients with implant-supported fixed prostheses: A 1-year follow-up study. *Int J Prosthodont* 2003;16:529–532.
36. Pagniano RP, Scheid RC, Clowson RL, Dagefoerde RO, Zardiackas LD. Linear dimensional change of acrylic resins used in the fabrication of custom trays. *J Prosthet Dent* 1982;47:279–283.
37. Valderhaug J, Floystrand F. Dimensional stability of elastomeric impression materials in custom-made and stock trays. *J Prosthet Dent* 1984;52:514–517.
38. Baker PS, Frazier KB. Water immersion procedure for making light-cured custom trays with wax spacers. *J Prosthet Dent* 1999;82:714–715.
39. Wirz J. L'importanza del portaimpronta individuale. *La Quintessenza Odontotecnica* 1999;16:489–497.
40. Takahashi Y, Chai J, Kawaguchi M. Equilibrium strengths of denture polymers subjected to long-term water immersion. *Int J Prosthodont* 1999;12:348–352.
41. Dixon DL, Breeding LC, Brown JS. The effect of custom tray material type and adhesive drying time on the tensile bond strength of an impression material/adhesive system. *Int J Prosthodont* 1994;7:129–133.
42. Peregrina A, Land MF, Wandling C, Johnston WM. The effect of different adhesives on vinyl polysiloxane bond strength to two tray materials. *J Prosthet Dent* 2005;94:209–213.
43. Huang FM, Tai KW, Hu CC, Chang YC. Cytotoxic effects of denture base materials on a permanent human oral epithelial cell line and on primary human oral fibroblasts in vitro. *Int J Prosthodont* 2001;14:439–443.
44. Campanha NH, Pavarina AC, Giampaolo ET, Machado AL, Carlos IZ, Vergani CE. Cytotoxicity of hard chairside reline resins: Effect of microwave irradiation and water bath postpolymerization treatments. *Int J Prosthodont* 2006;19:195–201.
45. Silva MM, Vergani CE, Giampaolo ET, Neppelenbroek KH, Spolidorio DM, Machado AL. Effectiveness of microwave irradiation on the disinfection of complete dentures. *Int J Prosthodont* 2006;19:288–293.
46. Vergani CE, Seo RS, Pavarina AC, dos Santos Nunes Reis JM. Flexural strength of autopolymerizing denture reline resins with microwave postpolymerization treatment. *J Prosthet Dent* 2005;93:577–583.
47. Witkowski S. (CAD-)/CAM in dental technology. *Quintessence Dent Technol* 2005;28:169–184.
48. Hegenbarth EA. Pilastrari implantari individuali e sovrastruttura realizzati con tecniche di design computerizzato. *Quintessence International* 2000;11/12:377–387.
49. Andersson B, Taylor A, Lang BR, et al. Alumina ceramic implant abutments used for single-tooth replacement: A prospective 1- to 3-year multicenter study. *Int J Prosthodont* 2001;14:432–438.
50. Glauser R, Sailer I, Wohlwend A, Studer S, Schibli M, Schärer P. Experimental zirconia abutments for implant-supported single-tooth restorations in esthetically demanding regions: 4-year results of a prospective clinical study. *Int J Prosthodont* 2004;17:285–90.
51. Park SW, Driscoll CF, Romberg EE, Siegel S, Thompson G. Ceramic implant abutments: Cutting efficiency and resultant surface finish by diamond rotary cutting instruments. *J Prosthet Dent* 2006;95:444–449.
52. Sgrò S. Principles of the metal framework design in metal-ceramic reconstructions. *Quintessence Dent Technol* 2002;25:21–52.
53. Rufenacht CR. *Principi di Estetica*. Milan: Scienza e Tecnica Dentistica Edizioni Internazionali, 1992.