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Complex Case

Rehabilitation in Light of New Technologies

CAD/CAM-Milled Full-Arch Restoration

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Abstract
This case report describes a step-by-step full-arch restoration, upper and lower, rehabilitated utilizing new technologies in dentistry.

CAD/CAM technology has changed not only the technician’s working process, but also the clinician’s, offering new benefits to the clinical workflow, as for example the possibility of using zirconia and its characteristics as a restorative material.

The clinician’s and technician’s professional backgrounds and relationship are critical to achieving better esthetic and functional results, while prosthetic success depends upon an in-depth knowledge of the materials and their properties and on carefully performed clinical procedures, which are still of utmost importance to obtain satisfactory results.

Key Words: zirconia-oxide, CAD/CAM technology, immediate implant load, clinical workflow, modern dentistry

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Introduction
Modern dentistry seeks new technologies to improve outcomes in restorative esthetics, achieve higher precision in every detail, and increase mechanical strength.

More than 100 computer-aided design/computer-aided manufacturing (CAD/CAM) systems are currently available and more than 95% of all objects used daily in dentistry are produced by CAD/CAM systems.

In recent years, CAD/CAM technology imported from the world of engineering has made it possible to use different dental materials, including zirconia, to simplify clinical and technical procedures. Wax, acrylic, alumina, lithium disilicate, gold, titanium, and alloys are examples of materials that can be employed in this new process. CAD/CAM technology completely changed the dental technician’s work process first, and the clinician’s at a later time, offering new benefits to treatment plan solutions.

This case report describes a step-by-step full-arch rehabilitation, focusing the attention on where, how, and why the new material—zirconia—and the new CAD/CAM technology entered into the treatment plan process, emphasizing their benefits and limitations.

Case Presentation

Patient Complaint and History
A 58-year-old male presented at the office complaining of high mobility of the upper arch, which was preventing him from chewing food correctly; pain at tooth #10 when in occlusion; and a fear of losing all his upper teeth and having to wear a removable denture. His desire was to avoid any removable solutions, even an interim one.

Allergic to aspirin and ibuprofen, the patient had not worn his removable upper prosthesis for the last two years due to pain and discomfort; since then, mobility and retro inclination of the upper teeth had increased while the mandible slipped forward when he closed his mouth, compensating for the malocclusion.

Facial analysis highlighted a parallelism of horizontal reference lines (bi-pupillary and commissural), symmetric facial midline with a 2-mm canting of the dental midline to the left, tilting of the upper occlusal plane to the right and the inferior one to the left, thin upper lip, and average lower lip. The profile was concave, the superior lip was 5 mm and the inferior lip 3 mm from the Rickets Esthetic Line, a nasolabial angle of 100 degrees and the inferior third of the face was not proportional to the middle one.

The dentofacial analysis (Fig 1) noted an average smile line, wide buccal corridor, and a 12-teeth smile width.

Intraorally (Fig 2), the superior dental midline did not correspond to the lower one, there was thin tissue biotype with presence of multiple recessions and lack of keratinized tissue on tooth #28, and generalized gingival asymmetries.

There was no referred muscle or articular pain. Functional analysis indicated a mandible anterior slide, centric relation (CR) and maximum in-
Figure 3: Panoramic x-ray evidenced severe bone loss, with horizontal resorption and some vertical defects, especially in the upper arch. There was asymmetrical vertical bone condition in the posterior maxilla, in which the available bone height and width on the left side did not allow implant insertion without a preliminary sinus augmentation procedure.

Figure 4: CT scan evaluation.

tercuspation that did not correspond, a 3-mm inverse overbite, and 1.5-mm inverse overjet.9

In terms of phonetic analysis, the “S” sound was done with vertical mandible movements with very little space present. In the “E” sound, the space in between the lips was 50% occupied by the upper incisors. In the “F” sound, the central incisor’s incisal edge was inside the lips’ foreshore, while in the “M” sound during the rest position the space exposed was about 5 mm.10

Preliminary Tests and Treatment
A preliminary plan to reduce pain, reestablish proper oral hygiene, perform scaling and root-planing, collect the essential information to obtain the correct diagnosis, and increase patient compliance was formulated as follows:

- antibiotic therapy to heal the periodontal abscess on #10
- periodontal evaluation prior to the hygiene session (there was plaque in 82% of the sites and bleeding on probing in 73% of the sites, pockets more than 5 mm deep in the superior and inferior teeth, and second-grade furcation involvement on the mesio-inclined #18)
- patient motivation, instruction, and oral hygiene rehabilitation
- full-mouth x-ray, panoramic x-ray (Fig 3), and computerized tomography (CT) scan (Fig 4)
- periodontal evaluation after the hygiene session (plaque presence and bleeding on probing
decreased at less than 10% on the plaque index and 24% were still bleeding on probing, and pockets more than 5 mm deep were still present on the upper and lower arch

- complete digital smile design photographic set
- study model mounted in an articulator in CR and a diagnostic wax-up (Fig 5)
- esthetic digital analysis (digital smile design).

A successful treatment plan depends upon a correct diagnosis, which must be achieved through meticulous data collection. All the data were shared with the dental technician, who transferred them to the study model for the diagnostic wax-up (Fig 5).

One of the indications was to evaluate the possibility of compensating for the patient’s serious malocclusion prosthetically with an incisal and canine guidance. To do so, it was necessary to increase the vertical dimension in CR, to permit the prosthetic retro inclination of the lower incisors, the vestibularization of the superior retro-inclined teeth, and recreate the correct overbite-overjet relationship compatible to the existing skeletal anatomy.

**Diagnosis and Treatment Plan**

Based upon the prosthetic project, x-rays, probing depth analysis, and study model evaluation, it was possible to formulate a diagnosis for this 58-year-old patient with high functional needs, advanced generalized chronic periodontitis in the upper maxilla, and mild generalized chronic periodontitis in the lower arch. In accordance with the patient’s desire to avoid any kind of removable prosthesis, the proposed treatment was an implant full-arch restoration immediately loaded on the upper arch (with extraction of the five remaining teeth); and on the lower arch an implant solution for the bicuspids and strategic extraction of #18. The treatment would consist of the following:

- Immediately loaded temporary screwed to the conical implant abutments in the upper arch with, at the same time, the placement of a reinforced temporary on the lower dentition.
- Osseous resective and mucogingival surgery of the inferior dental abutments to resolve the periodontal disease and the lack of keratinized tissue on #28, which would also be devitalized and rebuilt.
- Final layered zirconia implant restoration directly screwed to the conical abutments in the superior arch and cemented zirconia single crowns on implants #20 and #29, and a bridge from #21 to #28, utilizing zirconia frameworks.

The rehabilitation necessitated a multidisciplinary treatment, wherein every field of dentistry involved had its own therapeutic goals specific to the case:

- Endo-restorative: be as conservative as possible so as not to have weaker abutments.
- Prosthetic: rehabilitate both upper and lower arch to reestablish function and esthetics. Utilize a knife-edge finishing line to preserve as many dental structures as possible.
- Periodontal surgery: eliminate pockets, recreating a short junctional epithelium and increase keratinized tissue where necessary.
- Implant surgery: reach primary stability to be able to immediately load the implants.

**Treatment**

Treatment to rehabilitate the patient was sequenced accordingly to the “One Model Technique” protocol, described initially by Biscaro and colleagues and then by Agnini and colleagues. This protocol consists of three phases: pre-surgical, surgical, and final.

In the first step, arch size, bone volume, inter-arch relation in CR, and distance were evaluated preoperatively by means of a clinical examination and analysis of panoramic radiographs, periapical radiographs, CT scans, and study models mounted in an articulator.
Figure 6: Resin transfer plate to record the implant positions for the laboratory. It was also used as a surgical guide during the surgery.

Figure 7: Intra-surgical application of the surgical guide allowed for implant placement in reference to future tooth position. Six anterior implants were inserted; five straight and one tilted. Note the insertion of the tilted one.

Figure 8: Post-extraction gaps were filled with NovaBone, a completely absorbable calcium-phosphosilicate bone putty.

Based on the diagnostic wax-up, the dental technician built the lower reinforced temporary and a resin transfer plate for the upper arch (Fig 6), with a secure stop on the palatal vault and on the tuberosity, with an opening approximately at the level of the occlusal surface to use the plate as a surgical guide.

Surgical Phase
Chlorhexedine digluconate 0.2% mouthwash (Curasept, Curaden Healthcare s.r.l.; Milan, Italy) was prescribed to the patient, starting three days before surgery and then daily for one week. The surgery was performed under local anesthesia with articaine chlorhydrate with adrenaline 1:100.000 (Alfacaina N, Weimer Pharma; Rastat, Germany) and intravenous sedation with midazolam (Hypnovel 0.5-1 mg, Abbot s.r.l.; Milan, Italy).

After local anesthesia, the remaining teeth were extracted and sockets were carefully debrided.

A midcrestal incision was made dividing the available keratinized gingiva into half, excluding the maxillary tuberosity, to be as conservative as possible to give stability to the resin transfer plate. A full thickness flap was elevated, trying to preserve vascularization, thereby reducing the patient’s discomfort.

The vestibular bony wall was extensively exposed to allow the clinician a direct understanding of the patient’s sinus morphology during the drilling phase, since the surgery was set out to place a tilted implant. Regularization of the crest was performed with bony forceps and rotating instruments.

The maxillary was treated with six implants: five were straight (#9-11 in fresh extraction sockets carefully debrided; #6 and #5 were treated with an osteotome technique to increase bone density; and one, #4,
was tilted) (Fig 7). Bone quality was evaluated based upon Lekholm and Zarb’s classification\(^{14}\) and implants were placed following the manufacturer’s instructions and trying to optimize primary stability engaging the nasal and cortical sinuses.\(^{15}\)

In the post-extractive sockets, the gaps with the implants were filled with bone-grafting material (NovaBone; Jacksonville, FL), a calcium-phosphosilicate bone putty (Fig 8) that is completely absorbable and results in an osseo-stimulation process.\(^{16,17}\)

Straight and angled abutments were screwed to the straight and tilted implants, respectively.

In the same surgical session, in the lower jaw, the implant on #20 was placed and after an osseous resective surgery on #28, another implant was placed on #29.

**Immediate Provisional Restoration**

Copings for an open tray impression were positioned over the abutments and isolated with a sterile piece of rubber dam. Stabilization of the transfer plate in the patient’s mouth was checked with a secure stop on the palatal vault and on the tuberosity. Copings were connected to each other by orthodontic wire and composite (Protemp 4, 3M ESPE; Milan, Italy) and then fixed to the surgical guide with the same material.\(^{12,13}\)

After five minutes the impression copings and guide were removed, healing abutments were placed, and flaps were sutured with Gore-Tex 5/0 (Gore Medical; Flagstaff, AZ).

Implant analogs were screwed onto the impression copings and the entire complex compared to the surgical guide. The impression copings and analogs were positioned over the study model, checking the stop on the palatal vault as previously done in the mouth, converting the study model in the final master cast.\(^{12,13}\)

A screw-retained, metal-reinforced provisional\(^{18-21}\) was made and positioned in the patient’s mouth within 24 hours after the surgery, together with the lower reinforced temporary, with extraction of #24, and teeth were prepared with a feather-edge finishing line (Fig 9).

The immediate superior restoration comprised 12 teeth, and distal cantilevers were reduced.\(^{20}\) Full occlusal contacts in centric occlusion were maintained for all teeth, while lateral interferences were removed thanks to the anterior group guidance.

One month later, an osseous resective surgery in the lower jaw was performed (Fig 10) with a periosteal vertical mattress suture with Vycril 6.0 (Ethicon; Somerville, NJ) to resolve the periodontal disease.\(^{22-24}\)

**Final Restoration**

After four months of loading, with no pain or signs of inflammation (Figs 11 & 12), final impressions were taken in polyether (Impregum, 3M ESPE) for a master model to reproduce the tissue situation after the healing phase.

A wax registration, with a resin plate screwed into the superior implants, was taken to achieve the esthetic parameters and the jaw’s position in CR related to the provisional vertical dimension.

In addition a facebow and alginate impressions of the temporaries were taken and sent to the laboratory.

From this information the dental technician was able to build the prosthodontics project on the articulator. The occlusal relationship was carefully checked, with specific attention paid to anterior guidance (Fig 13). Function is always important, especially in this rehabilitation, where one of the goals was to compensate prosthetically a third class occlusion into a first class; due to this it was critical to project soft and well-balanced anterior guides. Silicone occlusal replicas, which would help to print the final restoration occlusal anatomy in the printing phase, were built with a verticulator.
Figure 11: Four-month follow-up, upper arch.

Figure 12: Four-month follow-up, lower arch.

Figure 13: Prosthodontics project, lateral view.

Figure 14: Implant position and inclination scanned with CAD technology. Note the peculiar shape of the laboratory scan abutment.

Figure 15: Wax-up analysis overlapped with the implant positional CAD.
Zirconia abutments cemented on titanium cores and connections were preferred to avoid screw fractures and increase the strength.

At this point new technologies entered into the treatment plan workflow.

Thanks to ZFX Evolution (Zfx GmbH; Dachau, Germany), a new, fully automated optical scanner (precision of 9 µ in a volume of 12 x 8 cms) whose measurement method is based on the principle of strip light projection, it was possible to scan the prosthodontics project and the implants’ positions. Implant abutments and soft tissue tunnel were recorded with specific match holders for the technical workflow; these indicated the apical-coronal position of the conical abutment (Figs 14 & 15).

Data acquired enabled the technician to section each one of the scans, allowing him to accurately shape and create the fixture’s connection anatomy.

With the highest possible scanning per solid (measurement in accordance with VDL, the European laboratory and field validation test procedures), models digitized by this new scanner provide the perfect basis for the construction of extremely complex geometries such as implant-supported, screw-retained bridge frameworks.

Maximum precision is achieved through a fully automated calibration of the device with every scan, as well as by the combination of an established measurement method with high-tech cameras—the LED light source of the strip light scanner projects a total of 128 line pairs on the surface of the model during a scan. These are recorded by two cameras with a resolution of 1,296 x 964 pixels. The swiveling and rotating positioning unit inside the scanner, on which the model is placed, guarantees precise detection of its entire details.

Once all the information was programmed into the software, the laboratory technician started working on the final restoration. From the plain scanned structure, the technician, using CAD software technology, was able to produce an extremely precise and accurate reduced anatomic structure (1.2-mm reduction), permitting the layering of the dental and gingival translucent masses (Figs 16 & 17).

This technology gave him total control of all the necessary parameters to build the final restoration: he could work with the opposing dentition and all the volume that would be present in the patient’s mouth, he could evaluate the screw axis and the customized design frameworks (Fig 18) inside the volume of the final restoration, and check the soft tissue profile both facially and palatally, modifying the soft tissue tunnel as well.
The milling center received the finalized file and, with the milling machine, created a zirconia framework directly screwed into the conical abutments and with correct chromatic characteristics to receive the esthetic layered ceramic on top (Fig 19).

Frameworks were tried in the mouth with the Sheffield Test in the upper arch and black silicone try-in paste to check the marginal and internal fit in the lower arch. The correct vertical dimension of occlusion in CR was controlled by adding acrylic resin (Pattern Resin, GC America; Alsip, IL) on the occlusal surface, and the incisal plane was checked with the esthetic resin placed on top of the upper arch framework.

After two bakes the bis-bake was tried in the patient’s mouth, checking all the esthetic, functional, and hygienic parameters and then sent back to the laboratory for the final glaze (Figs 20 & 21).
The final restoration was then cemented in the lower arch and screwed into the upper arch. The screw hole access was filled with composite (Filtek Bulk Fill, 3M ESPE; Seefeld, Germany) (Figs 22 & 23).

**Conclusion**

Especially in full-arch implant rehabilitation, as with the upper arch in the case described here, CAD/CAM technology provides a great benefit for modern dentistry, both from a clinical and a technical viewpoint. It enables us to obtain accurate and precise passivation (which is very difficult and technician skill-sensitive to achieve with traditional materials and protocols).

The high precision in reducing the scanned prosthodontics project structure, guaranteed with the CAD software, making space for the layered ceramic, allows technicians to know exactly how much structure has been digitally cut down in that particular area.

The technician’s traditional knowledge must be combined with the sophistication of this new software to enable our patients’ restorations to be more precise and have longer-term predictability (Figs 24 & 25).

However, while new technologies guarantee great benefits to both clinician and technician, standardized protocol and the operator’s experience are still the keys to success. Esthetic outcomes even now depend on our in-depth knowledge of materials and their properties.

The path to achieving the final restoration in complex multidisciplinary cases such as the one presented here is as important as the final result. Hence, in modern treatment-planning philosophy, in addition to the classic clinician goals such as surgical, prosthetic, and ergonomic success, the most important targets are patient-related—improving their quality of life not only at the end of the treatment but also during the entire treatment workflow. To accomplish this, patients must be involved throughout the entire process, from treatment planning, to the therapy itself, and maintenance of the achieved results.

Attaining accurate and effective provisionals, and reducing surgical steps and overall treatment time are basic steps in increasing the satisfaction of our patients.

**References**


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