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vol. 29 issue 4

Journal of Cosmetic Dentistry

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jCD vol. 29 issue 4
Journal of Cosmetic Dentistry

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EDITORIAL MISSION

The mission of the *Journal of Cosmetic Dentistry* is to educate AACD members, as well as other professionals in the field, on the art and science of cosmetic dentistry. We will endeavor to do this by publishing well-researched, peer-reviewed articles accompanied by high-quality, comprehensive clinical imagery. The objective is to enhance readers' knowledge and skills while showcasing the latest cosmetic techniques and procedures. The *Journal of Cosmetic Dentistry* will strive to help readers become better clinicians, so they can offer their patients the best—and most responsible—treatment possible.

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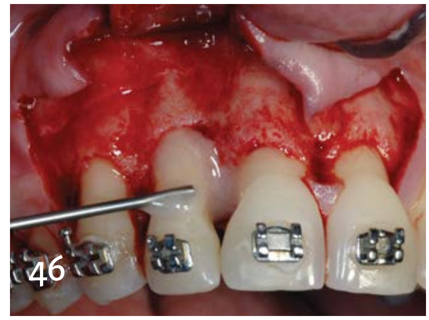
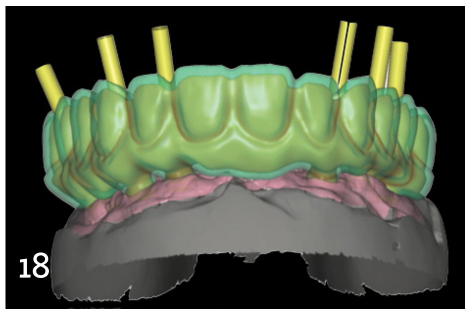
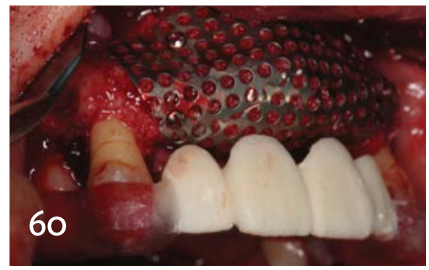
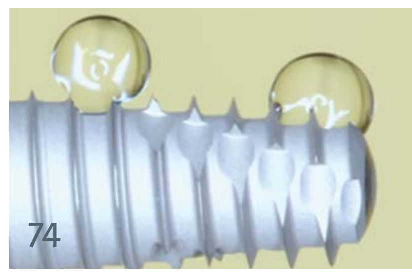
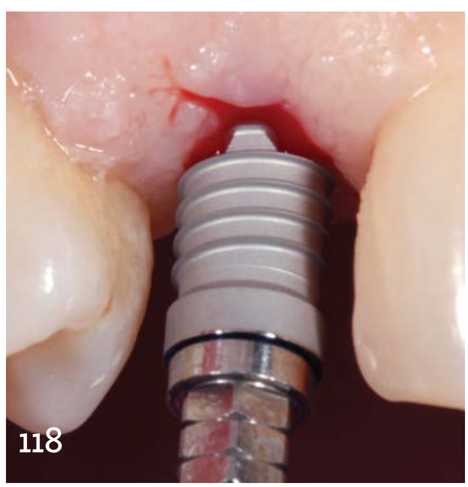
Features











Columns

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AACD Mission Statement

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In the "World Cup" of Dentistry, Everyone Wins!

"To win, the players and coaches from every team must work symbiotically at a high level, with excellent communication, skills, and attitude."

Look for the "play button" icon throughout this issue. The digital *jCD* will lead you to an online educational video for each article.

One of the greatest events in sports will be taking place this summer in Brazil. It involves high-performance teams from around the globe competing for the ultimate prize in international soccer competition…the World Cup.

To win, the players and coaches from every team must work symbiotically at a high level, with excellent communication, skills, and attitude. This is not a time for internal strife or "cliques." Individuals must work together seamlessly and produce a well-oiled, goal-scoring machine.

The concept of "team" influences our lives every day. Like most of you, I work with clinical, hygiene, and administrative teams at my private practice. In addition, I collaborate with specialists and laboratory technicians, who are part of my interdisciplinary restorative team. And we must not forget our "personal support teams" of family and friends, who provide us with much-needed sustenance and encouragement.

Dr. Maurice Salama approached us in the spring of 2013 with the concept of assembling some of the leading clinical teams from around the world into a single special issue. We were delighted that he wished to serve as Guest Editor for this issue. Dr. Salama discussed and coordinated the articles with each world team and they responded in a timely, conscientious manner. You will notice a "play button" at the beginning of each article, which links to the digital version of *jCD* as well as to a DentalXP video about the article. We are proud of this innovative collaboration. (Please note that *jCD*'s regular departments will return in the Spring issue.)

I know all of you will enjoy this exciting World Teams edition of *jCD*, of which I am extremely proud. Kudos to Dr. Salama and the AACD editorial team for their dedication in making this very special issue a success.

And, unlike the World Cup finals this summer, where only the winning country will get to hoist the World Cup trophy, all the teams that are "playing" in this issue are winners!

Edward Lowe

Edward Lowe, DMD, AAACD
Editor-in-Chief

Sharing a Team Experience

> **"Team dentistry brings out the very best in our collective clinical outcomes. We are often stronger as a group of skilled individuals than as a single practitioner, regardless of expertise."**

Maurice A. Salama, DMD

Dr. Salama is a clinical assistant professor of periodontics at the University of Pennsylvania and the Georgia Regents University College of Dental Medicine. He is an editorial review board member for the *Journal of Cosmetic Dentistry*.

Disclosure: Dr. Salama is a minority shareholder in www.DentalXP.com.

Dentistry continues to evolve at a rapid pace. Techniques and technologies are being developed and quickly implemented into treatment therapies around the world. With this momentum must come ways to disseminate the data in a concise and timely manner through key clinical educators. For the past six years, I have served as the scientific chairman of www.DentalXP.com, a highly regarded online dental education Web site, whose goal is to partner with educational academies and publications around the world like the AACD and *jCD* and provide a timely way to share this critical information via a "digital stage." With more than 125,000 global members in more than 150 countries, this online dental community is now well established.

This special World Teams issue of *jCD* was developed through such a partnership with Team Atlanta. We believe that by sharing ideas among different disciplines we can create the ideal groundwork for the establishment of new concepts that will lead us to optimal esthetic and therapeutic results. "Always inclusive, never exclusive" has always been our motto.

Team dentistry brings out the very best in our collective clinical outcomes. We are often stronger as a group of skilled individuals than as a single practitioner, regardless of expertise. Periodontics, prosthetics, orthodontics, oral surgery, endodontics, laboratory technologies, etc. have all been enhanced by new and developing technologies and science.

This special issue of *jCD* has brought some of the best teams in the world to your doorstep through both print and digital media. Italy, the United Kingdom, Israel, Japan, Spain, Ukraine, Brazil, and the USA are among the global nations represented in this issue. These same teams will be highlighted on www.DentalXP.com in digital presentations that will bring these text articles to life. Look for these links in your digital edition of the *jCD*. Enjoy the talent assembled here for your educational benefit. Share these articles with your own teams!

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"Worldly" Advice

The team at the *Journal of Cosmetic Dentistry* (*jCD*) is passionate about refining our educational offerings and inspiring our readers. Presented here are thoughts from our "World Team" authors about what excites them and what is critical to their team's success. The cover illustration represents the global scale of contemporary esthetic dentistry, in which building a high-performance, dependable dental team using advancements in technology is truly a global practice. The *jCD* and DentalXP teams hope you enjoy and are inspired by this issue.

Front cover illustration by Gary Cox, Cox & Co. (Black Earth, WI).

Q: What excites you about contemporary dentistry and why do you feel working as a team is critical to your success?

TEAM ITALY

Alessandro Agnini, DDS
Luca Dondi, DT
Matteo Dondi, DT
Andrea Mastrorosa Agnini, DDS




A: Patient quality of life is a primary objective in modern treatment planning, the goal being to attain it not only at the end, but also throughout the entire treatment process. This means that, especially in potentially edentulous patients—who likely are afraid and liable to refuse any type of removable prosthesis—it is critical to coordinate all the team members, from the hygienist to the dental technician, to ensure the carefully performed clinical and technical procedures that are of outmost importance to achieve a successful rehabilitation.

TEAM UNITED KINGDOM

Tidu Mankoo, BDS

A: An interdisciplinary treatment approach facilitates our always trying to create the optimum functional, biologic, and esthetic result for our patients. This is gratifying, as it enables us to make decisions regarding treatment that will be in the patient's best interest long term and enables us to achieve better outcomes. Working in a team makes dentistry more exciting and rewarding.


Cobi J. Landsberg, DMD
Ofer Sarne, DMD

TEAM ISRAEL

A: Contemporary dentistry enables clinicians to use advanced technology and at the same time encourages thinking, creativity, and development of sophisticated and exciting treatment modalities. Each day brings new discoveries and insights. As clinicians aware of our limitations and weaknesses, we welcome the input from other team members, especially in the planning and operative stages, but also when analyzing the end results. A team makes it possible to reach higher achievements and solutions, and encourages members to broaden their own professional horizons and discover their strengths and weaknesses. The team atmosphere stimulates thinking, performing, and finding solutions "out of the box."

TEAM JAPAN/SPAIN/USA

Tomohiro Ishikawa, DDS
Xavier Vela-Nebot, MD, DDS
Kenji Kida, DDS
Hidetada Moroi, DMD
Hajime Kitajima, DDS
Takahiro Ogawa, DDS, PhD

A: Being a member of a highly professional team gives us the support and additional insight of multiple specialties, which in turn allows us to hybridize procedures to give our patients the best possible outcome. The regenerative techniques and materials available to us as dental practitioners are always evolving and offer increasing opportunities for esthetic success. With these advances in long-term esthetic success, we are constantly improving our chances of making a positive change in patients' lives.

TEAM BRAZIL

Christian Coachman, CDT, DDS
Marcelo A. Calamita, DDS, MS, PhD

A: Teamwork is a fun opportunity to share concepts, possibilities, and techniques of treatment in order to reach the best option for each individual patient. Every team member can learn from pursuing common objectives that would not be accomplished working by themselves.

Nazariy Mykhaylyuk, DMD
Bogdan Mykhaylyuk, DT
Myroslav Solonko, DMD, MSc

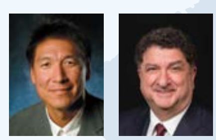
TEAM UKRAINE

A: In the world of dentistry, every specialty plays an important role. We read and learn to improve every day. But to learn everything by oneself is impossible. That is why creating a team—where every participant contributes his or her best to achieve the best treatment for our patients—is extremely important to achieving the best possible result in modern dentistry.

TEAM JAPAN/USA

Akiyoshi Funato, DDS
Ryohei Tonotsuka, DDS
Hitoshi Murabe, DDS
Makoto Hirota, DDS, PhD
Takahiro Ogawa, DDS, PhD

A: We believe that we can reach a higher place when we question, confirm, and improve ourselves. A good blend of critical thinking and creative minds surprises, thrills, and inspires us; a team approach makes this possible. As shown in our article, our team approach took us from knowing *of* osseointegration, to knowing *about* osseointegration; and from *using* osseointegration, to *utilizing* osseointegration.



TEAM USA

Stephen J. Chu, DMD, MSD, CDT
Dennis P. Tarnow, DDS

A: Contemporary dentistry is a dynamic field that is constantly evolving, thereby challenging our knowledge and thought processes in diagnosis and patient treatment. When working as a team, it is important to understand and appreciate the challenges each specialty faces to achieve the optimal treatment outcome.

Congratulations!

The AACD is proud to announce its Newly Accredited Fellows!

Since its inception in 1992, the AACD Fellowship program has provided an exceptional opportunity for dentists and laboratory technicians to greatly enhance their professional skills and knowledge in the areas of cosmetic and restorative dentistry.

It is unique in that it requires a dentist or laboratory technician to implement and demonstrate what they have learned at a level of proficiency. AACD credentialing processes are accessible regardless of location, educational background, or years of clinical experience. Candidates must have the resolve to meet challenges head-on, aspire to continually seek growth, and work persistently toward a worthy goal.

Fellowship is the highest level of achievement recognized by the American Academy of Cosmetic Dentistry®, in accordance with the AACD's mission of education and excellence. The status of "Accredited Fellow" of the AACD is granted after successful completion of all requirements. The AACD is pleased to announce the latest members to have attained Accredited Fellow status.

David D. Finley, DDS, FAACD
Monroe, LA
Member since: 2000

Sue C. LeBlanc, DDS, FAACD
Hammond, LA
Member since: 1995

Wynn H. Okuda, DMD, FAACD
Honolulu, HI
Member since: 1990

The three new Accredited Fellows will be recognized for their achievement throughout AACD 2014 in Orlando.

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> Wax, acrylic, alumina, lithium disilicate, gold, titanium, and alloys are examples of materials that can be employed in this new process.

Complex Case
Rehabilitation in Light of New Technologies

CAD/CAM-Milled Full-Arch Restoration

Alessandro Agnini, DDS
Luca Dondi, DT
Matteo Dondi, DT
Andrea Mastrorosa Agnini, DDS

The digital *jCD* version features a preview and link to an educational DentalXP video about this article.

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 outmost importance to obtain satisfactory results.

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

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)[1] 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.[2]

Figure 1: A 58-year-old patient presented with chronic generalized periodontitis. Average smile line, flat superior incisal plane, and wide left and right buccal aisles were observed in the dentolabial analysis.

Figure 2: The intraoral analysis showed plaque and calculus, as well as clinical attachment loss in the upper and lower dentition. The patient showed Class III occlusion associated with Kennedy Class II, edentulism in the posterior dentition, and mobility Grade II-III of the remaining anterior teeth.

The dentofacial analysis **(Fig 1)** noted an average smile line, wide buccal corridor, and a 12-teeth smile width.[3-5]

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.[6-8]

There was no referred muscle or articular pain. Functional analysis indicated a mandible anterior slide, centric relation (CR) and maximum in-

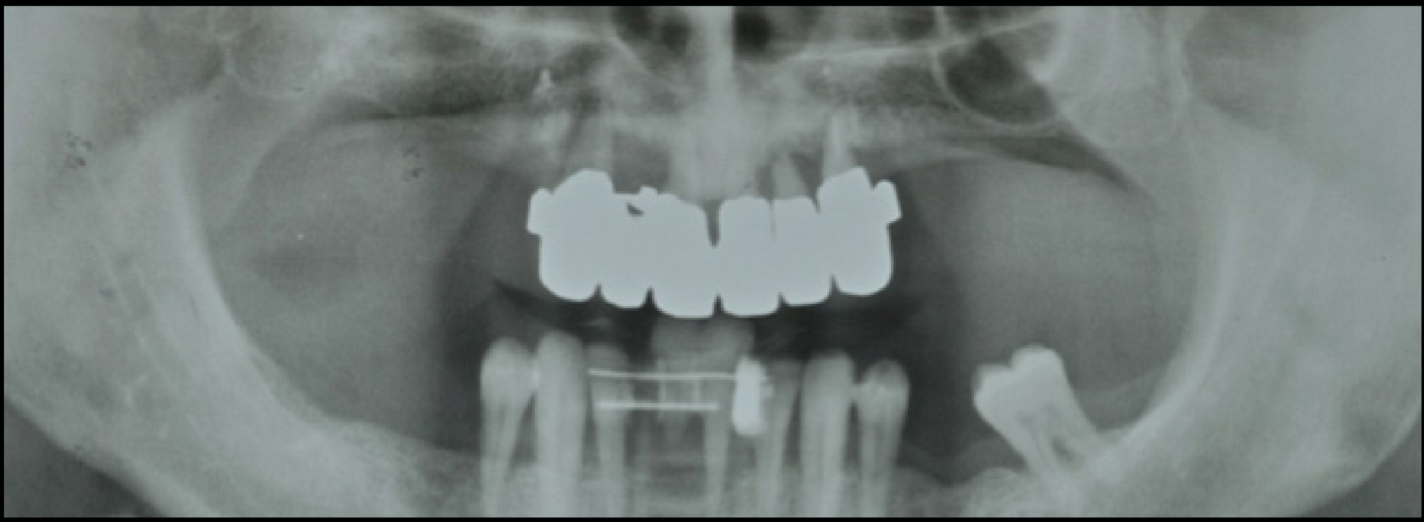

Figure 3: Panoramic x-ray evidenced severe bone loss, with horizontal resorption and some vertical defects, especially in the upper arch. There was asymmetrical vertical bone condition in the posterior maxilla, in which the available bone height and width on the left side did not allow implant insertion without a preliminary sinus augmentation procedure.

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

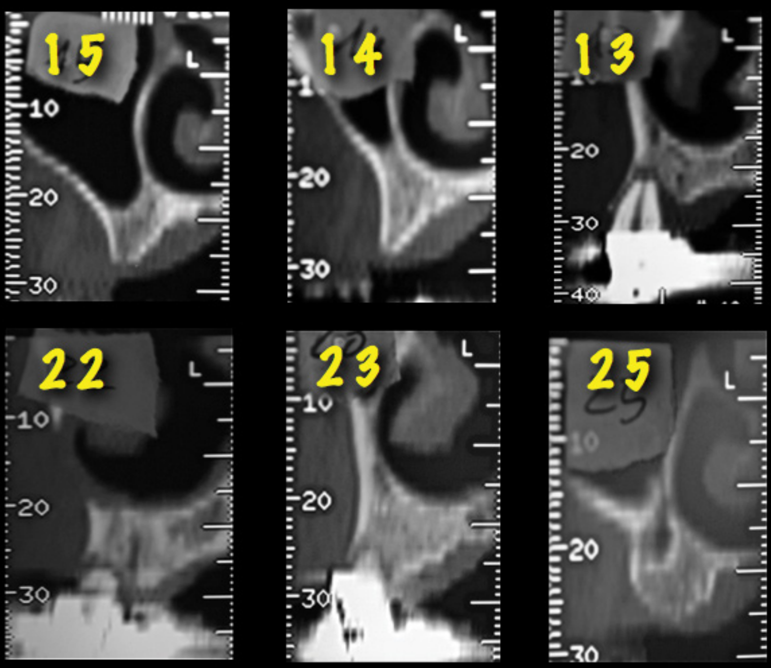

Figure 4: CT scan evaluation.

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.[11] 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.

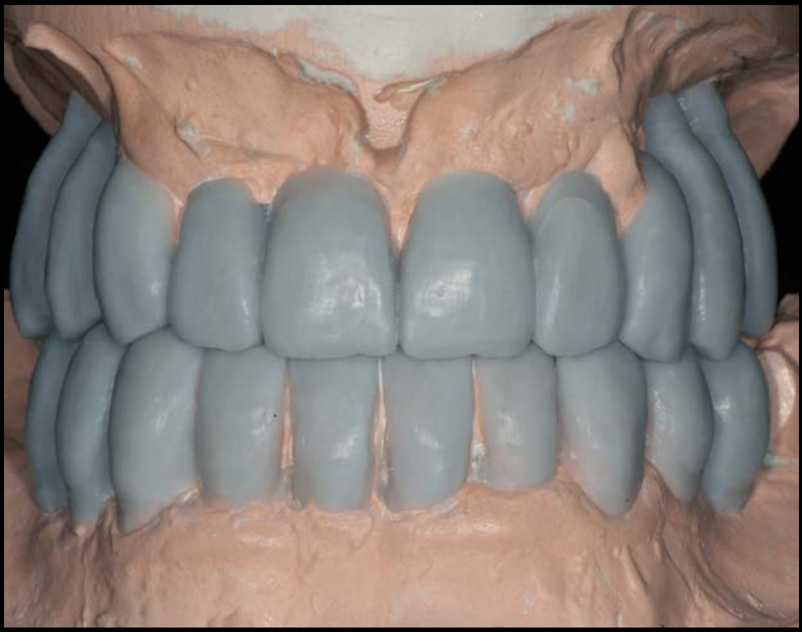

Figure 5: Diagnostic wax-up.

> "A preliminary plan to reduce pain, reestablish proper oral hygiene, perform scaling and root-planing, collect the information essential to make the correct diagnosis, and increase patient compliance was formulated."

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.[12,13] 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.

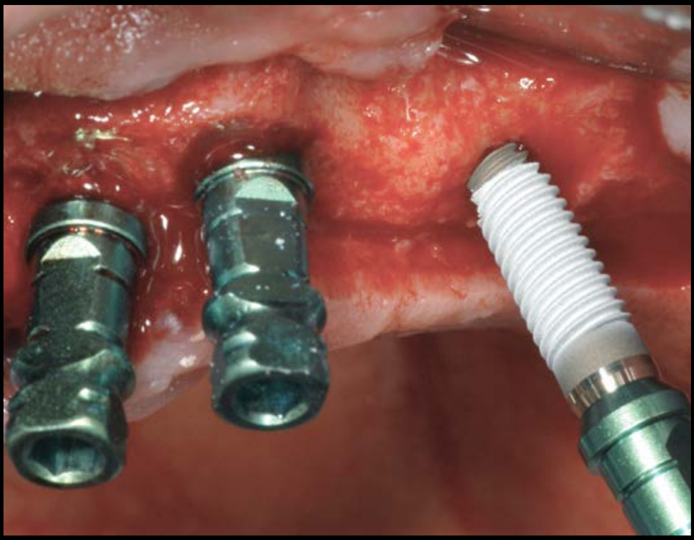

Figure 7: Intra-surgical application of the surgical guide allowed for implant placement in reference to future tooth position. Six anterior implants were inserted; five straight and one tilted. Note the insertion of the tilted one.

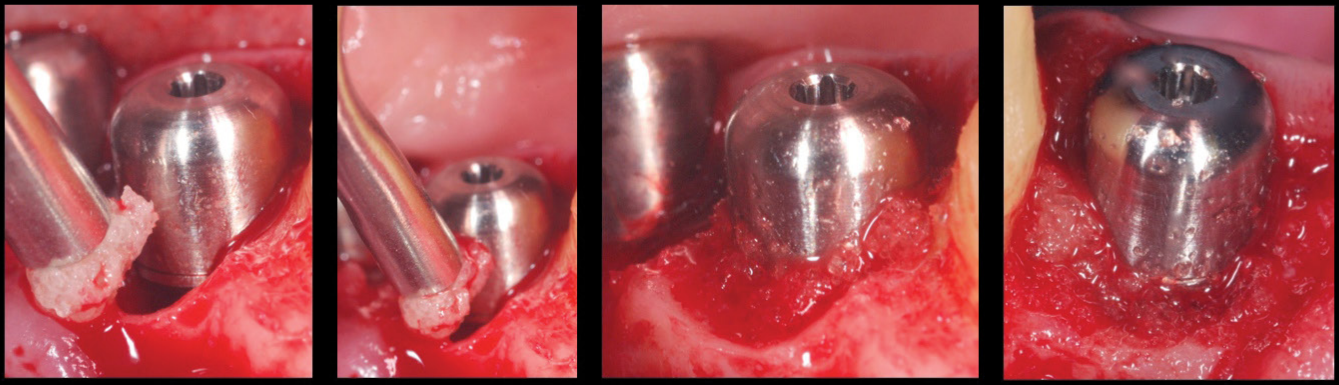

Figure 8: Post-extraction gaps were filled with NovaBone, a completely absorbable calcium-phosphosilicate bone putty.

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]

Figure 9: Dentolabial analysis with the provisionals in place.

Figure 10: Occlusal view, osseous resective surgery in the lower arch.

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.

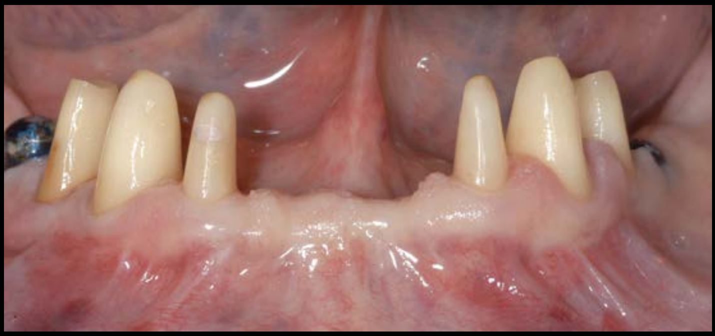

Figure 12: Four-month follow-up, lower arch.

Figure 13: Prosthodontics project, lateral view.

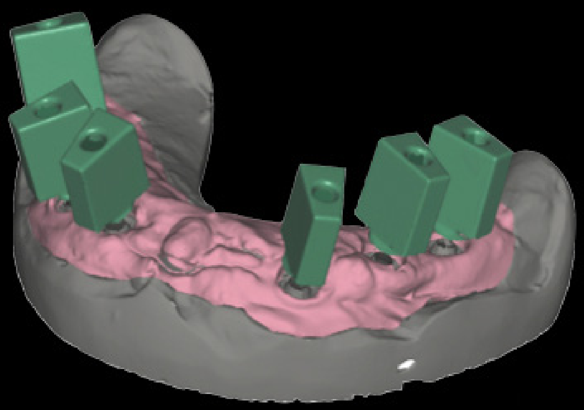

Figure 14: Implant position and inclination scanned with CAD technology. Note the peculiar shape of the laboratory scan abutment.

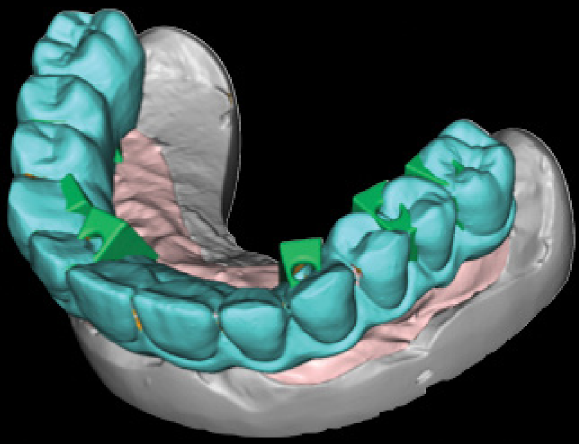

Figure 15: Wax-up analysis overlapped with the implant positional CAD.

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 9µ 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 VDI, 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.

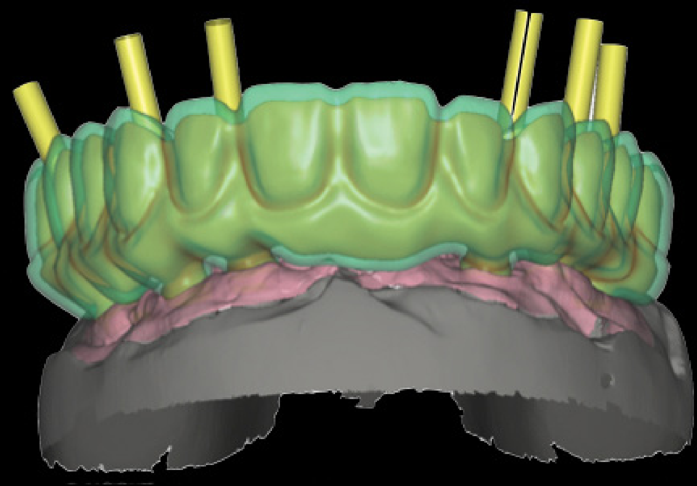

Figure 16: A 1.2-mm thickness reduction from the plain structure.

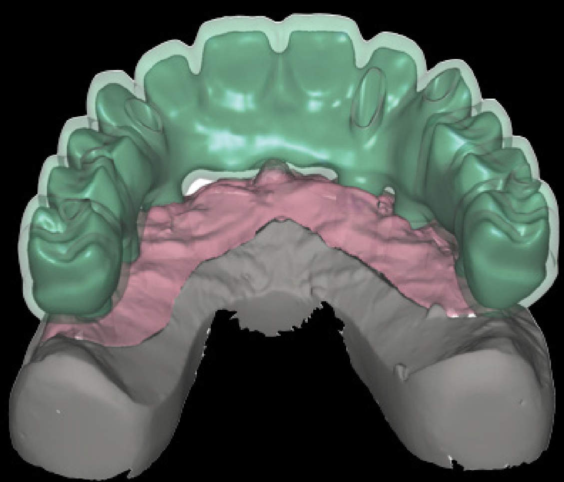

Figure 17: CAD view of the zirconia screw hole access.

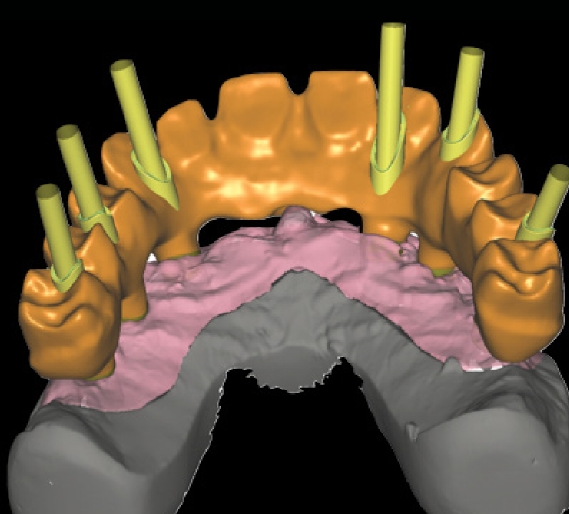

Figure 18: Framework and screw axis, CAD view.

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)**.

Figure 19: Zirconia frameworks on the master model.

Figure 20: Dynamic movements of the final restoration.

Figure 21: Upper arch, final restoration.

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.

Figure 22: Maxillary zirconium-oxide hybrid restoration screw-retained over zirconium-oxide abutments. Two implants were inserted in the location of the second premolar bilaterally. A zirconium-oxide fixed dental prosthesis was cemented on natural teeth from first premolar to contralateral. Correction of dental Class III was achieved, with normal overbite and overjet.

Figure 23: The patient's smile with the final restoration in place.

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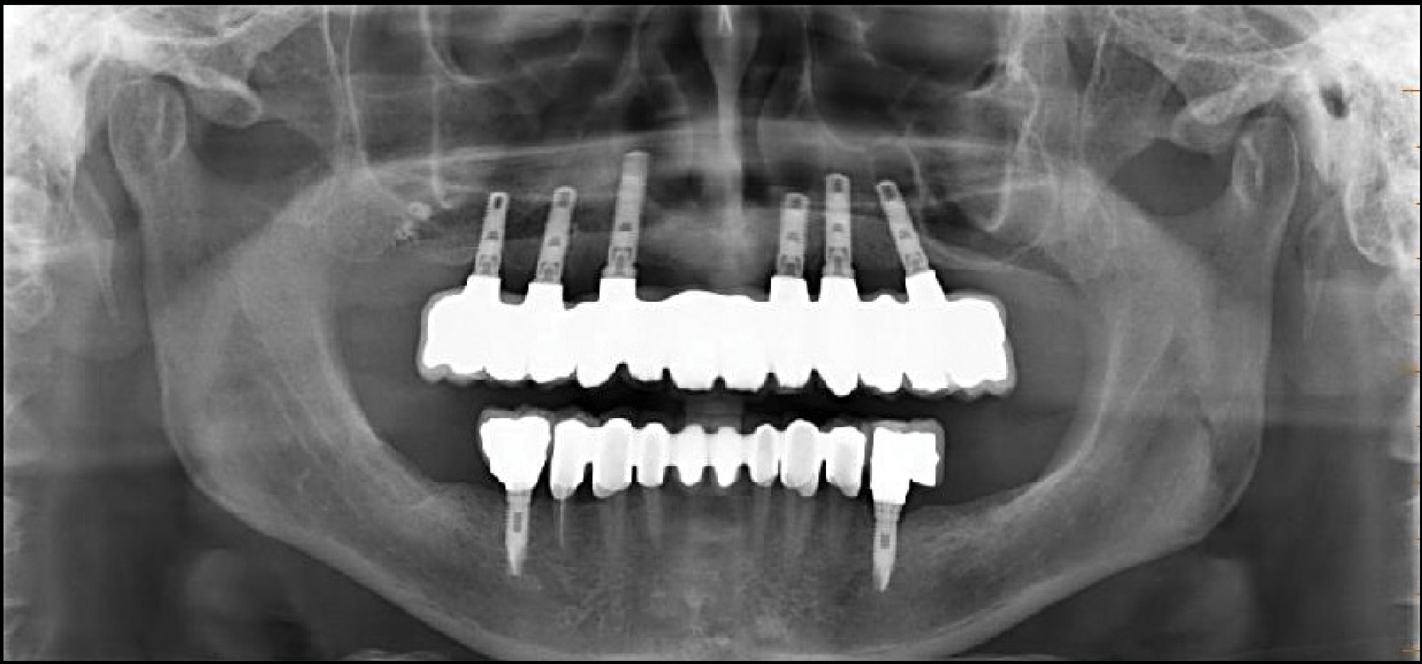

Figure 24: Three-year follow-up, panoramic x-ray.

Figure 25: Three-year follow-up, clinical images.

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

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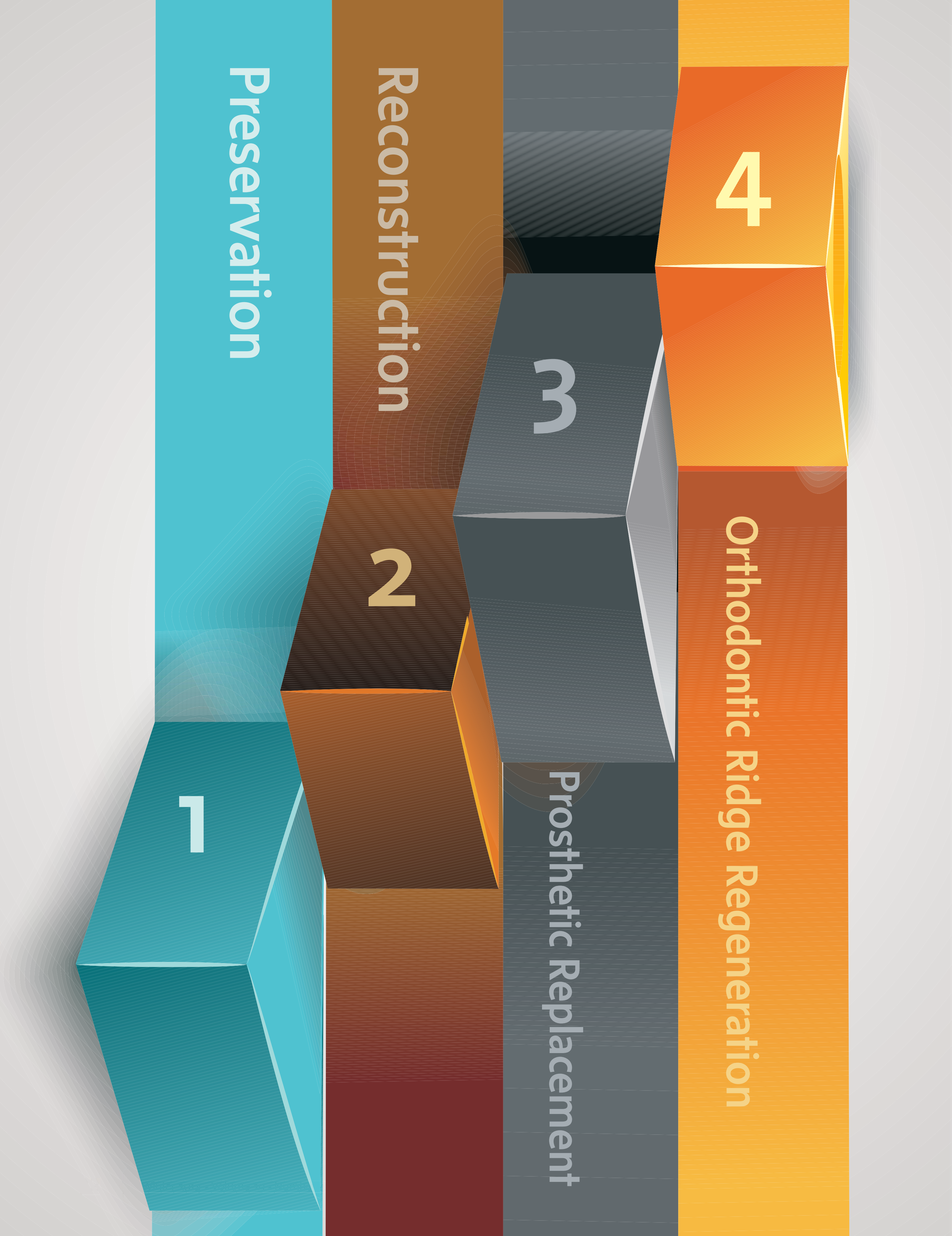
Preservation
Reconstruction
Prosthetic Replacement
Orthodontic Ridge Regeneration
1
2
3
4

ESTHETIC REHABILITATION of the Periodontally Compromised Dentition

A Novel Interdisciplinary Approach Using Orthodontic Extrusion and Dental Implants

The digital *jCD* version features a preview and link to an educational DentalXP video about this article.

Tidu Mankoo, BDS

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Abstract

Rehabilitation of esthetics in advanced periodontal cases presents a major challenge in dentistry today. Patients with advanced disease affecting teeth in the esthetic zone, where significant asymmetrical bone loss and tissue recession are present, constitute a challenging treatment-planning dilemma when choosing the optimum therapeutic option for long-term maintenance.

This article reviews a novel interdisciplinary approach for vertical augmentation of bone and soft tissues by means of orthodontic extrusion of severely periodontally compromised teeth, facilitating the restoration of esthetics with improved bone and soft tissue volume around immediate implants.

Key Words: implants, advanced periodontitis, peri-implant tissues, orthodontic extrusion, asymmetric bone loss, soft tissue loss

Introduction

Dental implants are firmly established as a mainstream protocol for the restoration of missing and failing teeth. An improved understanding of the biology of the peri-implant tissues and the limitations of implant treatment facilitates more predictable restoration of implants in the esthetic zone, particularly in relation to single tooth restorations. Nevertheless, more complex cases where significant bone defects and multiple missing or failing teeth are present still present challenging dilemmas in selecting the optimum restorative strategy. Predictable restoration of the bone and soft tissue architecture around multiple adjacent teeth restored with implant-supported restorations remains an elusive goal. There are three strategies that are broadly applied; these have been described[1] as preservation, reconstruction, and prosthetic replacement.

> **"Predictable restoration of the bone and soft tissue architecture around multiple adjacent teeth restored with implant-supported restorations remains an elusive goal."**

Strategy 1 (S1): Preservation

This is when the esthetics of the pre-treatment gingival anatomy are acceptable (e.g., by immediate placement protocols).[2-5] This strategy usually relates to periodontally healthy patients with teeth failing for structural or endodontic reasons.

Strategy 2 (S2): Reconstruction

This refers to surgical reconstruction of the bone and soft tissues by means of bone and soft tissue augmentation and grafting either prior to or at the same time as implant placement.[4,6-10] While good results for multiple tooth defects can be achieved in some cases, consistent esthetic outcomes are difficult to achieve in all cases and often require multiple and significant surgical interventions.

Strategy 3 (S3): Prosthetic Replacement

This is with pink acrylic, composite or porcelain. Certainly, good esthetics can be achieved quite readily with these protocols, but in practice, long-term hygiene maintenance and phonetics are not always ideal; this is of particular importance in the periodontally susceptible patient.

Advanced periodontal disease affecting teeth in the esthetic zone rarely leaves the teeth with an ideal pre-treatment anatomy, as the anatomic form and esthetics of both the interdental papillae and the labial gingival tissues are compromised by bone loss and tissue recession. Additional factors such as drifting of the teeth, hypermobility, and clinical attachment loss make these cases particularly difficult to solve from the point of view of good esthetics, function, and hygiene maintenance. This is especially true where the bone and tissue loss is asymmetrical and the prognosis of the teeth is poor or hopeless. Certainly we know that effective periodontal therapy can successfully maintain even severely periodontally compromised teeth[11-14] but often this can be esthetically compromised, with long clinical crowns and "black triangles" making esthetic rehabilitation difficult. Patients with a strong susceptibility to periodontal disease may still be treated successfully with dental impants,[15-18] albeit with a potentially increased risk of biologic complications.[19-22]

Strategy 4 (S4): Orthodontic Ridge Regeneration

In addition to the strategies above (S1-S3), a fourth strategy (S4) has been presented[1] for the esthetic rehabilitation of periodontally affected patients who have suffered significant and asymmetrical bone and soft tissues loss around failing teeth in the esthetic zone. This novel interdisciplinary treatment approach utilizes gentle orthodontic extrusion of failing teeth to achieve vertical bone and soft tissue regeneration/augmentation and facilitates conversion of the case from S3 or S2 to an S1.

Forced eruption and orthodontic extrusion have been suggested as viable options for implant site development[23,24] but may also play a valuable role in the vertical augmentation of bone and soft tissues in advanced periodontal cases with failing teeth in the esthetic zone.[1,24-26] Careful sequencing of the treatment is important and involves the following:

- control and stabilization
- orthodontic extrusion of failing/compromised teeth
- extraction and implant placement
- restoration with fixed crowns and bridges.

Phase 1: Control and Stabilization

Periodontal and anti-infective therapy, caries treatment, and structural control along with any necessary endodontic treatments are performed to eradicate disease and stabilize the teeth. The periodontal treatment would usually involve root surface debridement, oral hygiene instructions, anti-microbial therapy, and necessary extractions.

Phase 2: Orthodontic Extrusion of Failing/Compromised Teeth

This is gentle orthodontic extrusion of the periodontally compromised teeth in the esthetic zone, as well as bucco-lingual and mesio-distal alignment. This may also necessitate adjunctive endodontic treatments and implant placement in the posterior segments for anchorage. Vertical bone and soft tissue volume gain is achieved through coronal repositioning of clinical attachment levels. Treatment typically takes some three to six months of active movement and a minimum of three months of fixed retention (with continued periodontal supportive therapy) to allow full mineralization of healthy, mature bone and maturation of soft tissue contours around the compromised teeth. These in turn provide appropriate extraction sites for the next phase.

Phase 3: Extraction and Implant Placement

This involves surgical and prosthetic protocols to preserve the bone volume and thicken the labial soft tissues in order to maintain stable soft tissue esthetics.[27]

Phase 4: Restoration with Fixed Crowns and Bridges

This refers to restoration of the teeth and implants with single units or small bridges following current biologic principles with simple prosthetic designs optimized for easy home care and maintenance. Regular and ongoing supportive periodontal/peri-implant care and maintenance is essential.

The aim of this treatment (S4) is to enable restoration of failing teeth with implant-supported crowns and/or bridges with a more or less "normal" and harmonious gingival architecture. It involves a careful systematic interdisciplinary approach to treatment planning and case management. This concept would seem to be of particular benefit in cases of asymmetric bone and soft tissue loss in the esthetic zone (as illustrated by the two clinical cases to follow).

Benefits

The substantial benefits with the use of this approach are as follows:

- A less invasive surgical approach. The surgical experience for the patient is significantly reduced by the avoidance of large and complex grafting procedures and hence reduced morbidity (e.g., preservation rather than reconstruction or replacement).
- Ease of prosthetic design and fabrication. As the prosthetic restoration essentially restores only the clinical crown contours, then technical fabrication of the restorations is straightforward, with fewer technical complications.
- Biomechanical. Crown-to-implant ratios are optimized and large complex prosthetic reconstructions involving cantilevers are avoided.
- Facilitated oral hygiene and maintenance. Achieving the final prosthesis design (i.e., single crowns or short-span bridgework with ovate pontics) and the symmetrical soft tissue contours certainly facilitates simple maintenance and hygiene procedures for the patient, with obvious long-term benefits in terms of maintaining healthy peri-implant tissues.
- Phonetics. The reconstitution of a more or less normal or "ideal" relationship of the teeth and soft tissues avoids phonetic complications found in large-span implant-supported bridgework in patients with advanced bone loss.
- Biological. It could be argued that a more biologically ideal restoration of bone and soft tissues contours is achieved in contrast to more complex grafting procedures (i.e., regeneration of the patient's own bone and tissue volume with minimal surgical intervention and bone grafting).
- Stability. This approach negates the risk of resorption and gradual loss of graft volume seen with most surgical grafting techniques used to rebuild large volumes over multiple tooth spans. Both the clinical cases discussed below show excellent maintenance of soft tissue and bone volume over time despite being complex and difficult at presentation.

However, the concept is not without its limitations, the most obvious of which is the need to still have teeth present with some clinical attachment in the affected areas (i.e., the esthetic zone). In addition, the interdisciplinary treatment required necessitates well-coordinated, systematic management of the case with excellent communication within the team.

The advantages/limitations of this concept are summarized in **Table 1**.[1]

Table 1. Advantages and Limitations of S4.

Advantages	Limitations
• Abundant vertical and horizontal augmentation/regeneration of bone and gingival tissues is possible. • Minimizes the surgical intervention for the patient and reduces morbidity of the procedures. • Facilitates ideal implant positioning and biomechanics (crown-to-implant ratio). • Simplifies the design and fabrication of the prosthetics. • Creates a near-optimum, stable, esthetic soft tissue outcome. • Facilitates oral hygiene and maintenance procedures for the patient as normal tooth contours and simple ovate pontics are utilized. • Provides predictable, stable regenerated bone and tissue volume. • There is little or no resorption of grafts as the regenerated volume is essentially normal (not grafted) host tissue. • There is little or no difference in overall treatment time.	• The failing teeth must have some clinical attachment still present and must be maintainable for the duration of the orthodontic treatment and retention/stabilization. • Any periodontal disease or endodontic involvement needs to be controlled prior to orthodontic extrusion. • The interdental papillae will not be "perfect" (i.e., fully regenerated to pre-disease levels); however, the soft tissue result is as good as/or better than that achieved with any surgical reconstruction. • The patient must still have teeth in the affected areas.

Clinical Cases

The treatment concept is illustrated by two clinical cases.

Case 1

The first case involved a 35-year-old female with generalized aggressive periodontitis **(Figs 1-3)**. She had been a smoker but had quit some 18 months before presentation, and had no other relevant medical history. Achieving restoration of the patient's oral health, function, and esthetics is obviously a complex challenge. From an esthetic standpoint, the asymmetrical pattern of bone and soft tissue loss in the anterior maxilla creates a dilemma in terms of treatment options that requires careful consideration, as follows:

- Is there a way to treat and maintain the severely compromised anterior teeth and achieve an esthetic outcome? Can gingival harmony be achieved predictably in this way? Can further gingival recession be prevented if we are to successfully eradicate the pocketing and disease in the area? The answer is clearly "no," unless the maxillary left incisors and canines are crown-lengthened and we accept long teeth across the entire anterior maxilla with permanently splinted crowns to stabilize the hyper-mobile teeth.
- Should a complete clearance be performed, followed by osseous resection and a complete implant restoration in order to reduce the maxillary ridge so that the gingival tissues can be recreated prosthetically? While a possible option, it also is a drastic one in light of the patient's age; we cannot underestimate the psychological impact of losing all of one's teeth at the age of 35. Second, complete implant-supported restorations where there is significant vertical tissue loss or reduction do present long-term challenges in terms of maintenance and oral hygiene procedures. Third, there are definitely teeth in the patient's mouth that could be saved and maintained for the long term with the correct treatment and maintenance, so should these be extracted?
- Can we remove the maxillary incisors and predictably recreate the ridge to create ideal esthetics, restoring the teeth with bridgework on teeth or implants? What is the long-term stability of vertical augmentation in terms of durable soft tissue esthetics, particularly in a relatively young patient?

After initial periodontal and anti-infective therapy and removal of most of the hopeless posterior

Figure 1: Case 1 smile at presentation. Note postured upper lip to try to hide the unattractive teeth and "black triangles."

Figure 2: Frontal view at presentation with lateral periodontal abscess on #11, gingival inflammation, and recession with triangular tooth form and asymmetric gingival contour.

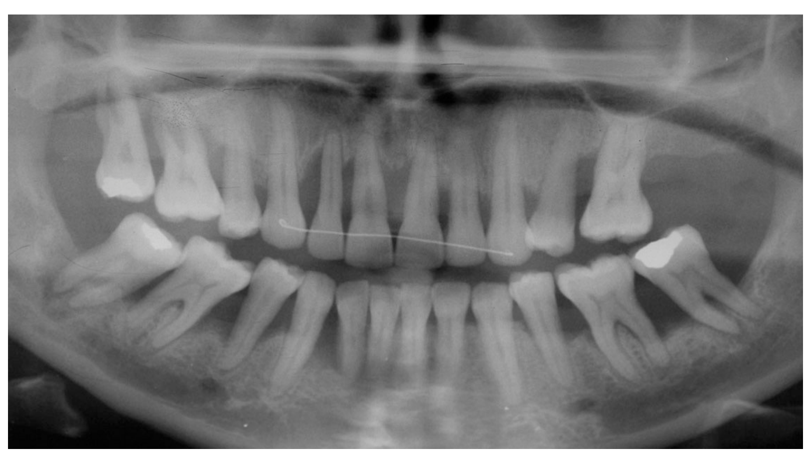

Figure 3: Orthopantogram (OPG) at presentation showing widespread bone loss. There were deep probing depths of 9 mm or more on many teeth.

Figure 4: After initial periodontal and anti-infective therapy, lingual appliances were used to extrude and align the teeth with careful control of the vector of extrusion.

Figure 5: The teeth and gingival margins were moved coronally. Rough composite bonding was applied to mask the enlarged "black triangles."

teeth, orthodontic treatment was commenced using lingual appliances to align the mandibular anterior teeth and extrude and align the maxillary anterior teeth with careful control of the vector of extrusion **(Figs 4 & 5)**. Extremely gentle forces were utilized along with supportive periodontal therapy throughout the treatment time. Implants were placed in the posterior healed sites with an osteotome technique to lift the maxillary sinus floor.

After six months of orthodontic treatment, extrusion was still needed on teeth ##12-21 but maintaining esthetics was becoming difficult as treatment progressed. The teeth were further extruded using magnets in the roots of the incisors and in the provisional bridge **(Figs 5-8)**. Cementing magnets (American Dental Systems; Vaterstette, Germany) into the base of the pontics and into the roots leaving space between allows for gentle extrusion to occur. As the teeth are extruding, further clearance is obtained by reducing the magnets and roots with diamond burs until the desired extrusion is achieved. A retention period of three months was allowed for full mineralization of the bone around the extruded teeth and maturation of the bone and soft tissues before removal of the incisors and placement of the immediate implants into the sockets. The sockets were naturally very shallow and the implants (NobelReplace Groovy, Nobel Biocare; Yorba Linda, CA) were placed toward the palatal aspect of extraction sockets. Labial voids were filled with anorganic bone mineral (Bio-Oss, Geistlich AG; Wolhusen, Switzerland), with connective tissue grafts sandwiched between the buccal gingivae and the healing abutments **(Fig 9)**. After the provisionalization phase **(Fig 10)**, the final crowns and bridges were fabricated **(Figs 11 & 12)**. The final results at five-year follow-up show the excellent maintenance of a good functional, biologic, and esthetic outcome with stability of the vertical regenerated bone and soft tissues contours **(Figs 13-16)**.

Figure 6: Conversion of upper appliance to utilize a provisional bridge using magnets to further extrude the incisor roots.

Figure 7: Retention phase and provisionals. Note the gingival margins are now coronal to the level on the right canine.

Figure 8: Radiograph showing stabilized bone around extruded roots.

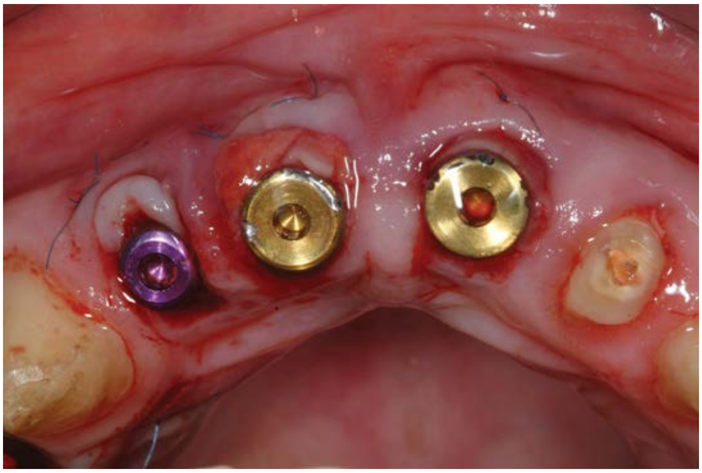

Figure 9: Implants placed into extraction sites 3 mm apical and 2 to 3 mm palatal to final labial gingival margins with grafting of anorganic bovine bone mineral into labial voids, and small connective tissue grafts sutured between labial gingivae and healing abutments.

Figure 10: Provisional bridge after three months with additional implant placed at #22.

Figure 11: Retraction cord placed at cementation of crowns to prevent cement violating peri-implant tissues.

Figure 12: Final result at two-year follow-up showing excellent esthetics and symmetrical gingival contours.

Figure 13: Two-year follow-up shows excellent maintenance and stability of the soft tissue contours.

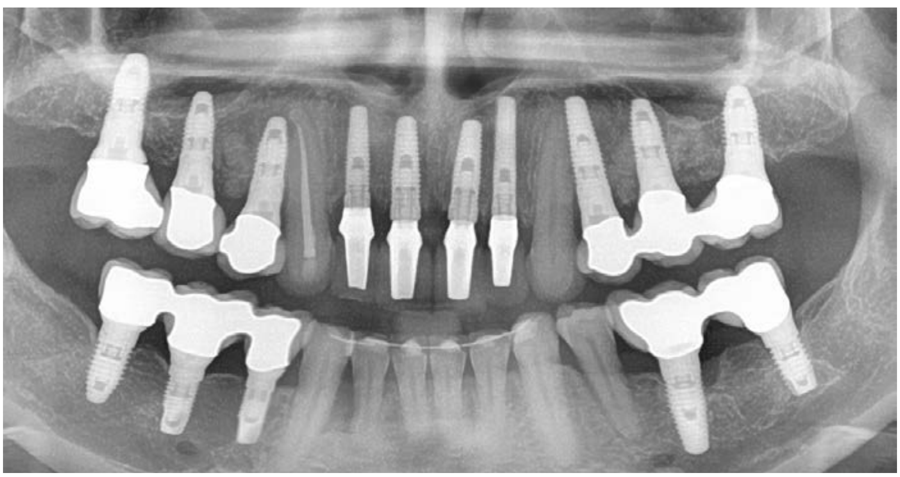

Figure 14: OPG at five-year follow-up.

Figure 15: Five-year close-up of maxillary anterior teeth showing the quality of the soft tissue outcome and excellent esthetics around implant restorations.

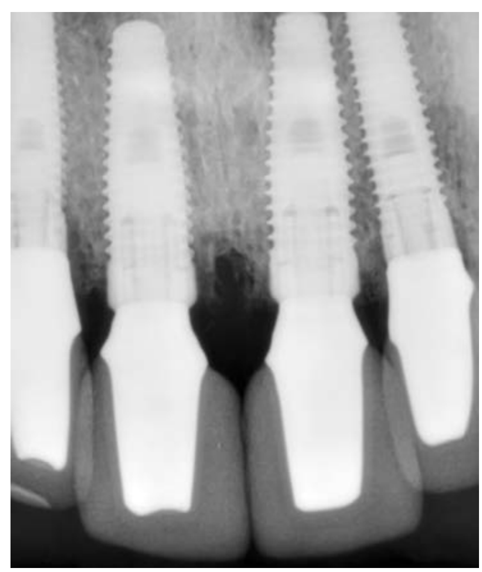

Figure 16: Periapical image at five years shows stable or improved of bone levels and density around implants.

Case 2

The second patient, a 53-year-old female, was referred to the practice in May 2006 suffering from generalized chronic advanced periodontitis with generalized bone loss, deep pocketing, gingival recession, and tooth mobility along with significant drifting and splaying of the teeth **(Figs 17-20)**. She had a history of smoking 25 cigarettes a day for 25 years but had quit in 2001 with no other relevant medical history. Many teeth were also structurally and endodontically compromised and again there was an uneven pattern of bone loss with many of the teeth clearly hopeless with the exception of the lower anterior teeth and maxillary right second premolar. In the anterior maxilla, there was significant bone loss with a "bell-shaped" pattern.

The considerations for treatment options here are somewhat more straightforward than in the previous case. Certainly a clearance followed by a complete implant restoration with the gingival tissues recreated prosthetically would be a feasible option and many might consider this the option of choice. However, the S4 approach in cases of this kind may also have considerable merit. It would aim to create the basis for an S1-type restoration wherein the clinical crown is restored with more or less normal tissue and alveolar ridge height. This facilitates many of advantage outlined in **Table1**.

Figure 17: Case 2 smile at presentation.

Figure 18: Frontal view of pre-treatment situation. Note the poor periodontal condition, splaying and drifting teeth.

Figure 19: Preoperative OPG shows generalized severe bone loss.

Figure 20: Pre-treatment periapical image of maxillary incisors.

Treatment was staged in a similar way to that discussed above, including periodontal therapy, and the maxillary teeth were extruded to bring the bone and soft tissues to a more favourable coronal position using very light forces and gentle extrusion over six months, with a further three months' retention to allow full mineralization of the bone **(Figs 21-24)**. Implants were placed in the posterior mandible and periodontal supportive therapy was continued throughout the treatment. Immediate implants were placed as described above and an immediate provisional bridge was fabricated for the maxilla **(Figs 25 & 26)**. The final restorations were then fabricated **(Fig 27)**. Given the starting point, an exceptional result was achieved and the four-year follow-up images **(Figs 28-30)** demonstrate the excellent maintenance of health, function, and esthetics with stability of the soft tissue esthetics and gingival contours.

Figure 21: Occlusal view of upper arch lingual appliance. The lower anteriors were also aligned.

Figure 22: Final results of extrusion in the maxillary arch and alignment in the mandibular arch.

Figure 23: OPG at completion of orthodontic treatment showing levelling of bone architecture.

Figure 24: Periapical radiograph of maxillary incisors at completion of orthodontic treatment.

> **"This novel interdisciplinary treatment approach utilizes gentle orthodontic extrusion of failing teeth to achieve vertical bone and soft tissue regeneration/augmentation and facilitates conversion of the case from S3 or S2 to an S1."**

Figure 25: Postoperative view of maxilla with provisional bridge fitted over implant heating abutments retained on the upper right premolar and implant in #24 position. CT grafts and frenectomy were also performed.

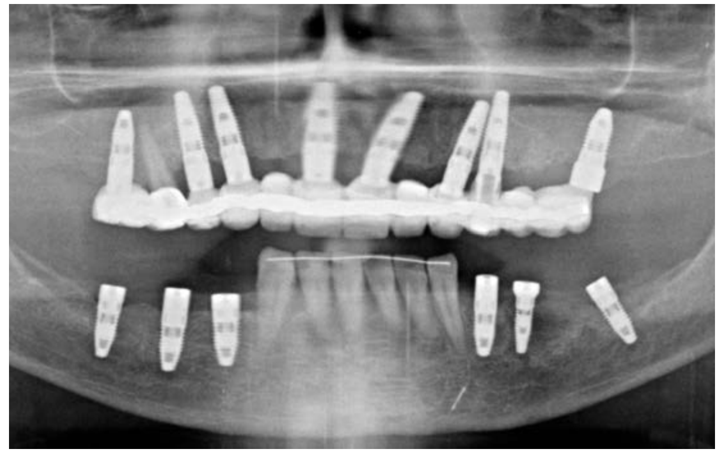

Figure 26: Postoperative OPG of provisional bridge and implants.

Figure 27: Frontal view of completed case. Note harmonious gingival contours and normal tooth dimensions with vertical gain of tissue height in the maxilla.

Figure 28: Four-year follow-up showing excellent maintenance of soft tissue levels and esthetics.

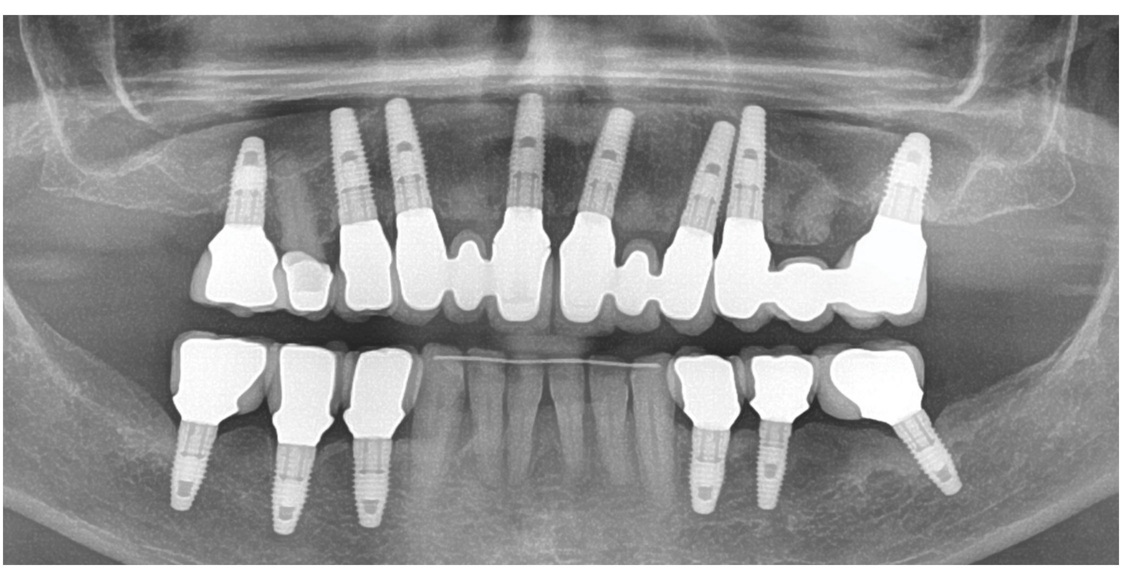

Figure 29: OPG at four-year follow-up shows maintenance of bone levels around implants.

Figure 30: Close-up of four-year follow-up shows excellent stability with symmetrical soft tissue contours.

Summary

In patients affected by advanced periodontal bone and tissue loss, an interdisciplinary approach, which involves periodontal therapy, followed by orthodontic extrusion of compromised or failing teeth prior to extraction and replacement with implants, may offer an excellent method for esthetic rehabilitation particularly in the vertical augmentation and regeneration of bone and soft tissues. This may improve the functional, biologic, and esthetic outcomes of implant-supported restorations in these cases. Meticulous surgical and prosthetic management and excellent hygiene and maintenance are essential.

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“Meticulous surgical and prosthetic management and excellent hygiene and maintenance are essential.”

Dr. Mankoo owns a private practice in Windsor, Berkshire, United Kingdom and is visiting professor at Universitat Internacional de Catalunya (International University of Catalunya), Barcelona, Spain.

Disclosure: The author did not report any disclosures.

SEQUENCING of Periodontal Procedures and Orthodontic Treatment

For Long-Term Esthetic Outcome: A 5-Year Case Report

The digital *jCD* version features a preview and link to an educational DentalXP video about this article.

Cobi J. Landsberg, DMD
Ofer Sarne, DMD

Abstract

Severe cases of periodontal disease often require periodontal surgery and realignment of teeth. Surgical techniques have been developed that attempt to minimize postsurgical gingival recession and compromise the interdental papillae. A case report is presented in which reversal and correction of a deteriorating maxillary frontal dentition were effectively achieved through combined use of periodontal and orthodontic principles. The treatment plan included the control of periodontal inflammation, restoration of lost attachment apparatus, realignment of anterior dentition, stabilization of occlusion, and minor periodontal plastic surgery. The anticipated loss of a maxillary lateral incisor was avoided. Restoration of a pleasant smile with nicely aligned teeth and esthetic gingival contours was achieved. The correct sequencing of the procedures involved was considered a key factor for the long-term esthetic outcome.

Key Words: sequencing, esthetics, bone, mucogingival, regeneration, orthodontics, periodontal

"Since the 1960s, several surgical techniques have been developed to minimize postsurgical gingival recession and preserve the interdental papillae."

Introduction

Advanced periodontal disease is primarily characterized by severe attachment loss and reduction of alveolar bony support. The condition usually presents as tooth mobility, migration, spacing, and marginal gingival recession. In the maxillary anterior region, the functional damage is usually accompanied by compromised esthetics. Patients with advanced periodontal disease often require periodontal surgery that frequently results in additional gingival recession and esthetic deterioration. Since the 1960s, several surgical techniques have been developed to minimize postsurgical gingival recession and preserve the interdental papillae.[1-7] These techniques are specified by the effort to prevent unnecessary excision of healthy gingival tissue, prevent reduction of bony tissue, and locate the flaps as far coronally as possible by advanced flap procedures and suturing techniques.

Orthodontic realignment of migrated, severely periodontally involved teeth is usually initiated after surgical control of inflammation.[8] The timing of this treatment after periodontal surgery is still controversial. A long healing period and radiographic evidence of bone apposition before initiating orthodontic tooth movement has been advocated.[9] Others claim that better results are achieved when orthodontic movement starts shortly after completion of periodontal regenerative therapy.[10-14]

This article describes a case that utilized the "regeneration-then-early-orthodontics" approach, which was applied to restore function and esthetics in a maxillary anterior dentition severely compromised by periodontal disease. The fulfillment of esthetic requirements by periodontal plastic surgery, carried out only after realignment of the anterior dentition, is also demonstrated.

Figure 1: Preoperative smile demonstrates tooth migration with developing interdental spaces and gingival recessions at the maxillary lateral incisors.

Case Presentation

A 48-year-old female presented complaining of migrating maxillary incisors, appearance of interdental spaces, and overall unpleasant presentation of her smile **(Fig 1)**. Based upon previous dental consultation, the patient anticipated replacement of the right lateral incisor with an implant restoration. She wished to restore function and esthetics of the maxillary anterior dentition. Her medical condition was normal and non-contributory. Clinical examination revealed tooth mobility, migration, and spacing in the maxillary incisor area, particularly the right lateral incisor that had drifted both horizontally and vertically. Generally, probing pocket depths ranged from 3 to 5 mm. However, the right lateral incisor presented with a 7-mm pocket, coupled with moderate loss of papilla height on the mesial aspect and labial gingival marginal recession. Additionally, the left lateral incisor presented with a minor (yet esthetically disturbing) labial recession, and a 6-mm pocket depth on its labio-distal aspect. The marginal tissue was neither overtly inflamed nor bleeding. Radiographic examination revealed generalized moderate bone loss with severe vertical bony defect on the mesial aspect of the maxillary right lateral incisor **(Figs 2a & 2b)**.

The patient was diagnosed with generalized moderate-to-advanced periodontitis, accompanied by secondary occlusal trauma. The prognosis was good, except for the maxillary right lateral incisor, which was considered unsecured. After discussing treatment options, the patient agreed to undergo periodontal and orthodontic therapies in an effort to restore function and esthetics without removing the lateral incisor. The objectives were to control periodontal inflammation, restore lost attachment apparatus, realign the anterior dentition, harmonize marginal gingiva contours, and stabilize the occlusion. However, contrary to the authors' suggestion, the patient declined periodontal surgery as the first choice to control inflammation and regenerate lost tissues.

Figures 2a & 2b: Preoperative radiographic images reveal deep vertical bony defect mesially on the left lateral incisor.

Figure 3: Fixed edgewise brackets with Cu-Ni-Ti wire to level and align the maxillary incisors.

Clinical Procedure

Non-Surgical Therapy

At the patient's request an attempt was made to control inflammation non-surgically; this included five consecutive sessions of scaling and root-planing.

After three months, periodontal examination revealed significant improvement in pocket depths.

Orthodontic Therapy (Initial Phase)

A standard edgewise stainless steel fixed appliance was bonded to the entire maxillary arch. Minimal forces to level and align the maxillary incisors were used via a super-elastic thin wire (made of copper, nickel, and titanium). Special effort was made to improve the vertical, horizontal, and long axis positions of the maxillary right lateral incisor **(Figs 3 & 4)**. Six months after initiation of orthodontic therapy teeth alignment improved, but no significant enhancement of gingival contours around the right lateral incisor was achieved **(Fig 5)**. At this point, the patient agreed to return to our first strategy (i.e., implementation of periodontal regenerative surgery prior to orthodontic treatment).

Periodontal Regenerative Surgery

Since the brackets and wire were already mounted, it was decided that they remain attached and non-active. This would help stabilize the teeth that required surgery. The papilla preservation technique was implemented. Sulcular incisions were made around the right canine, the right lateral incisor, and the right and left central incisors; vertical releasing incisions on the right canine and left central incisors enabled full

Figure 4: Deep defect mesially on the lateral incisor at initiation of orthodontic treatment.

Figure 5: Six months after initiation of orthodontic treatment, improved teeth alignment was noted, but recessed gingiva around the right lateral incisor was evident.

Figure 6: Deep, partially contained bony defect was noted mesially and buccally on the right lateral incisor. Note that unnecessary detachment of the central buccal papilla was avoided.

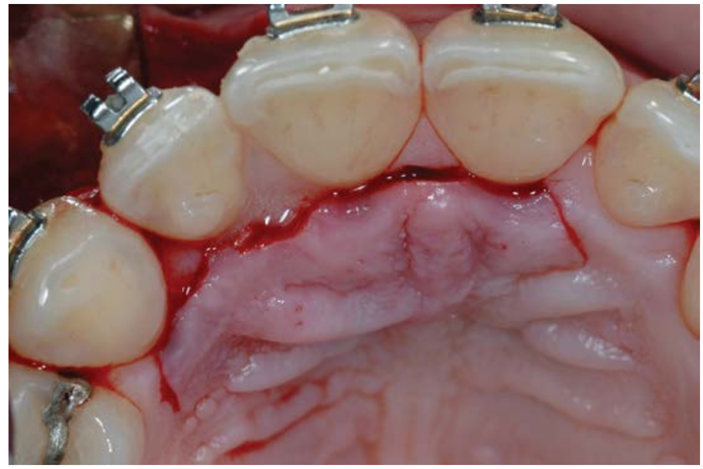


Figure 7: Palatal flap design with preservation of interdental soft tissue; both mesial and distal papillae of the lateral incisor remained part of the buccal flap.

thickness flap elevation both buccally and lingually, fully exposing the deep defect on the right lateral incisor **(Figs 6 & 7)**.

The defect was degranulated and the roots planed and treated with enamel matrix derivatives **(Fig 8)**. The defect was filled slightly coronal to its contained part, with deproteinized bovine bone particles **(Fig 9)**. Flaps were closely adapted to the root surfaces and sutured by first intention, using 6-0 polyamide sutures to ensure complete coverage and isolation of the bone grafted defect **(Figs 10 & 11)**. The orthodontic wire was immediately connected, as the mobility of the lateral incisor was expected to increase and interfere with the healing process.

Postoperative Instructions and Follow-up

An analgesic (naproxen sodium 275 mg, Teva; Petah-Tikva, Israel), was prescribed for three days, four times daily. The patient was instructed to abstain from brushing and flossing around the surgical area until suture removal (14 days), and to consume only soft food during the first week. She was also instructed to avoid any other trauma to the treated area. After two weeks, the patient was instructed to floss and use the coronally directed roll technique with a Clinic Gum Protector extra-soft toothbrush (Jordan; Oslo, Norway). After four weeks, she changed to a stronger (yet still soft) toothbrush (Elmex, GABA; Switzerland) using the Bass brushing technique. During the first four weeks, the patient used a 0.2% chlorhexidine solution rinse (Tarodent, Taro; Haifa, Israel) for one minute twice daily. She was also recalled for professional supragingival biofilm control: weekly for the first four weeks, then monthly for the first six months.

Orthodontic Therapy (Definitive Phase)

Five weeks after surgery, complete wound closure was evident with maximal protection of the grafted bony defect. Partial root coverage of the right lateral incisor was noted; however,

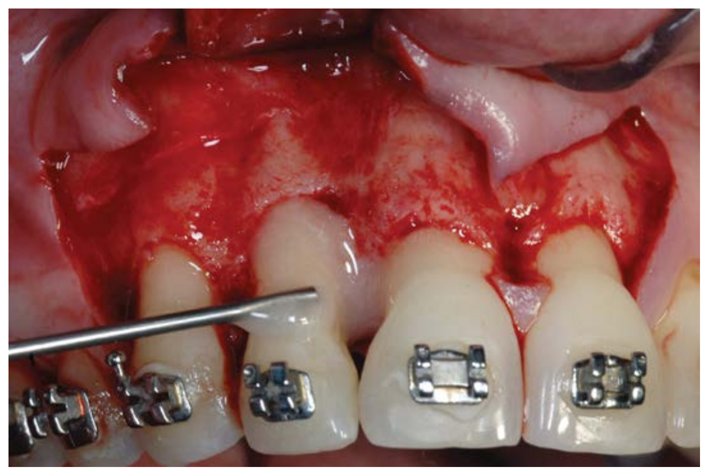


Figure 8: Following defect degranulation and root-planing the root was treated with enamel matrix derivatives.

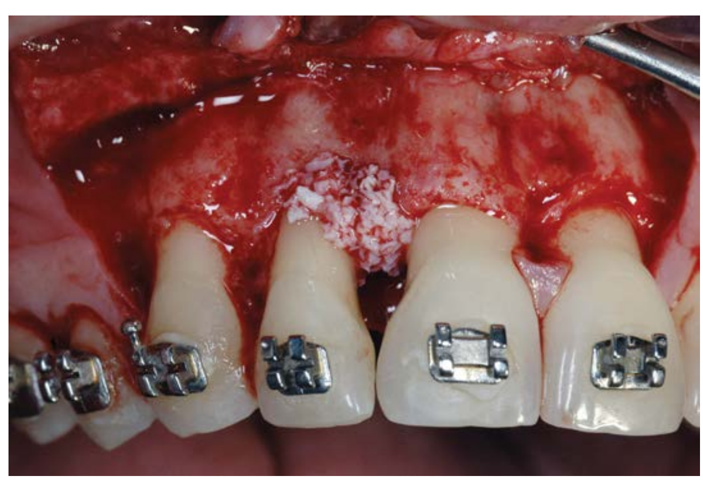
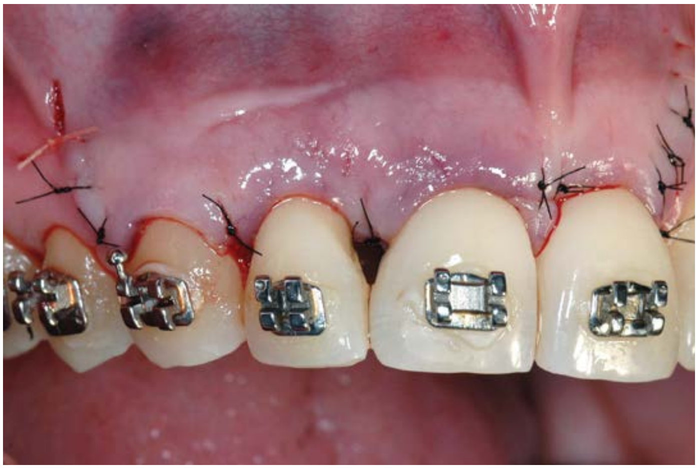
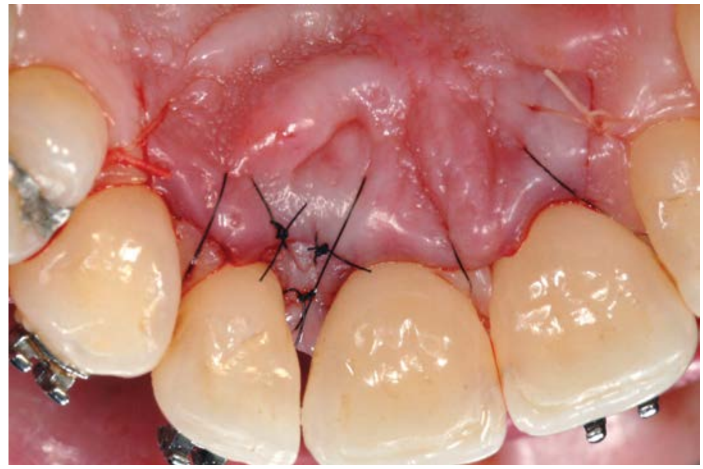


Figure 9: Deproteinized bovine bone particles were grafted in the contained and non-contained parts of the bony defect.





Figures 10 & 11: 6-0 polyamide simple sutures were used to approximate the buccal and palatal flap by primary intention.

the associated interdental mesial papilla level remained unchanged **(Fig 12)**. The aim was to advance the interdental papilla coronally. Since no space existed between the right lateral and right central incisors, reactivation of orthodontic treatment at this phase was targeted mainly at root approximation rather than at the crowns of these teeth. This was achieved by using stainless steel light wires and minimal orthodontic forces. Additionally, some minor interproximal reductions were made, mesially and distally to the maxillary right incisors, to create a stable and more apically located contact area **(Fig 13)**. During orthodontic treatment, the patient's motivation was maintained by visiting the dental hygienist on a monthly basis. The fixed appliance was debonded after seven months, and the teeth were splinted with a braided stainless steel wire, bonded with a composite resin **(Fig 14)**. The referring restorative dentist bonded a composite resin to the mesio-incisal edge of the mesially tilted right central incisor.

At completion of active treatment, clinical examination showed a well-functioning, natural-looking anterior dentition. Minor gingival recession at the left lateral incisor was still noted **(Fig 15)**. Radiographic examination revealed favorable root/crown ratios (although minor apical root resorption of the right lateral incisor was evident), dense crestal osseous profiles, and appreciable bone fill in the grafted intrabony defect **(Fig 16)**.

Figure 12: Initiation of second phase of orthodontic treatment (five weeks after surgery). Light stainless steel wires were activated to approximate between roots of the right lateral and central incisors.

Figure 13: Seven months post-initiation of orthodontic treatment (second phase), improved papillae and marginal tissue position were achieved; however, mesial inclination of the right incisor was noted.

Figure 14: At completion of orthodontic treatment, the front anterior sextant was splinted with a braided stainless steel wire, bonded with a composite resin.

Figure 15: At completion of active treatment, a composite resin was bonded to the mesio-incisal edge of the inclined right incisor. Significant tooth alignment and improved gingival contours were achieved, but minor root recession of the left lateral incisor was still present.

Figure 16: At completion of orthodontic treatment, dense osseous crestal profiles with appreciable bone fill were present. However, minor periapical resorption of the right lateral root was noted.

Periodontal Plastic Surgery

Six months after orthodontic therapy, a root-coverage procedure at the left lateral incisor could be implemented. It was decided to limit the surgical field to the involved tooth to avoid potential damage to the almost ideal gingival contours achieved on the neighboring teeth. Because crestal bone distally of the tooth was partially missing, with some loss of papilla height (Miller Class III)[15] **(Figs 17 & 18)**, a bilaminar surgical approach was implemented.[16] Vertical oblique incisions were made at the mesial and distal line angles of the crown, extending up to a distance of approximately 3 mm apical to the mucogingival junction line. New surgical papillae were elevated by splitting the anatomical papillae, followed by full thickness flap elevation up to the mucogingival line, revealing the full extent of the exposed root and the neighboring alveolar bone **(Fig 19)**. Horizontal splitting incisions were made to free the flap completely from muscle attachments and the underlying periosteum and to allow coronal flap advancement without tension.

The root was planed and smoothed with periodontal curettes and rotatory finishing diamond burs up to the level of premeasured soft tissue attachment. A thin and mostly dense connective tissue graft was harvested from the palate and placed to cover the exposed root surface **(Fig 20)**. After de-epithelialization of the adjacent papillae, the flap was coronally advanced and secured at a level slightly coronal to the cemento-enamel junction (along with the underlying connective tissue graft) using 7-0 polyvinylidene fluoride (Serag-Weissner; Naila, Germany) simple sutures at the vertical line incisions. A 6-0 polyamide (Ethilon, Ethicon; Somerville, NJ) sling suture around the tooth achieved further graft anchorage. No periodontal dressing was used **(Fig 21)**.

Figure 17: Left lateral incisor shows a Miller Class III gingival recession.

Figure 18: Minimal crestal bone resorption was present between the left lateral incisor and the canine.

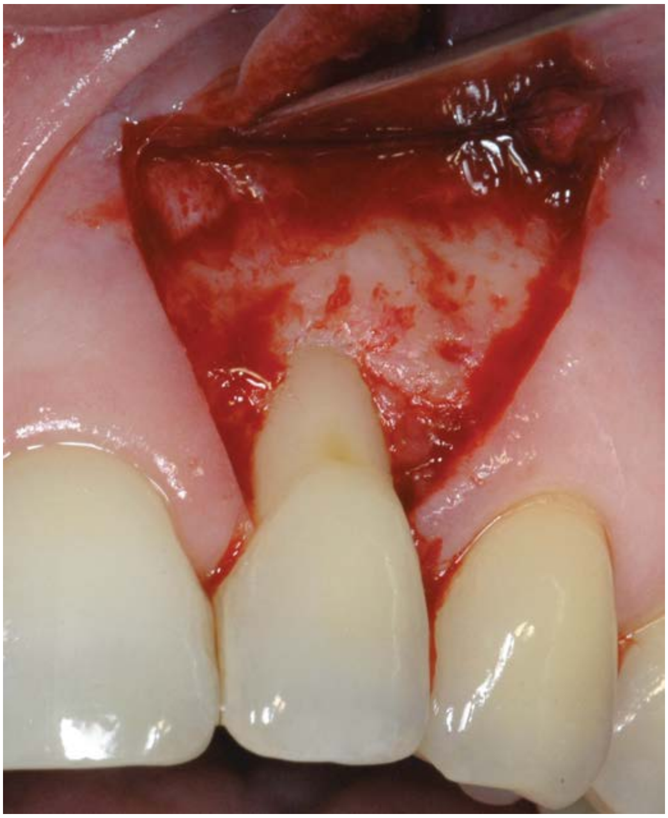


Figure 19: A triangular-shaped split-full-split flap was elevated and the root surface planed.

Figure 20: A thin dense connective tissue graft was placed to cover the exposed root and 2 to 3 mm around the bone.

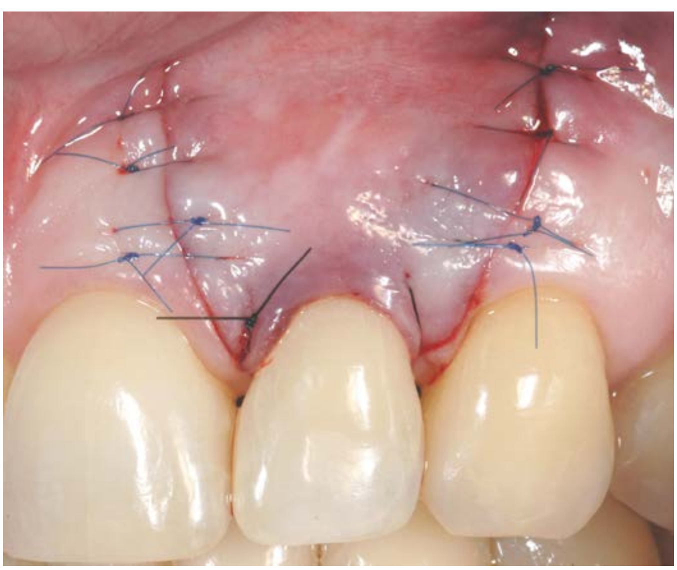


Figure 21: A combination of 6-0 polyamide and 7-0 polyvinylidene fluoride sutures was used to fix both the grafted tissue and the coronally advanced flap.

> **"The esthetic appearance of the maxillary anterior dentition is determined to a considerable degree by the contour, size, and health of the labial gingiva and the interdental papillae."**

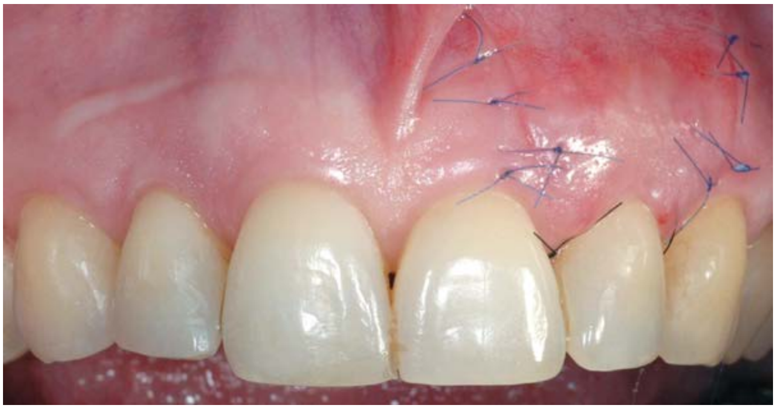


Figure 22: Two weeks after the root-coverage procedure, healing was uneventful. The patient was instructed to use the coronally directed roll technique for harmless brushing and effective plaque control.

Figure 23: At case completion, the right lateral incisor was properly intruded, and the marginal gingiva and interdental papillae regained normal appearance.

Figure 24: At completion of treatment, the patient presented with a nice smile, showing well-aligned teeth with healthy and nicely contoured gingiva.

Postoperative Instructions and Follow-up

Instructions similar to those after the regenerative surgery were given **(Fig 22)**. However at two months the patient was instructed to return to the coronally directed roll technique using a stronger (still soft) toothbrush (Elmex, Gaba; Switzerland). To complement biofilm control the patient was instructed to use a single tufted brush (Paro 1003, Esro; Kilchberg, Switzerland) splayed and used to sweep along the gingival line of the maxillary incisors.

At the end of treatment, the patient presented with a nice smile and reasonable tooth alignment, together with well-defined interdental papillae and no recessed marginal tissue **(Figs 23 & 24)**. Radiographic examination revealed solid crestal profiles, with considerable bone fill at the right lateral incisor **(Fig 25)**. A four-year follow-up revealed a successfully maintained long-term esthetic result **(Fig 26)**. At the five-year postoperative follow-up the upper right central received a new Class IV composite restoration that improved the patient's smile **(Figs 27 & 28)**.

Figure 25: The radiographic view revealed solid crestal bone profiles with bone fill at the right lateral incisor.

Figure 26: At the four-year follow-up, the successful results had been well maintained.

Figure 27: Five-year follow-up image, frontal view. The Class IV restoration of the maxillary right central had been renovated; however, slight gingival recession on the tooth was noted.

Figure 28: Five-year follow-up image. The patient exhibited a pleasing smile with maintained tooth alignment and esthetic gingival contours.

Discussion

The esthetic appearance of the maxillary anterior dentition is determined to a considerable degree by the contour, size, and health of the labial gingiva and the interdental papillae. The normal contour, shape, and consistency of the gingival tissues may change dramatically with the occurrence and perpetuation of periodontal inflammation, especially when coupled with tooth migration. In this complex case, the patient's treatment was based upon the following rationale:

A. Periodontal regenerative procedure is the preferred choice in patients with deep defects.

A non-surgical approach may be encouraged for the maxillary anterior dentition.[17] However, in patients with very deep pockets, proper defect debridement with efficient root and gingival curettage may be achieved only by surgical therapy.[17-19] The deep bony defect of the maxillary right lateral incisor was localized primarily on the mesio-buccal aspect. Therefore, a rather extensive labial flap was elevated. This significantly improved visibility and access to the surgical area for meticulous curettage of the diseased root and bony defect, and for a controlled and adequate implementation of the bone grafting process.

Treatment of intrabony periodontal defects with a combination of an enamel matrix derivative and natural deproteinized bovine bone material has been shown to significantly improve clinical parameters such as probing depth, clinical attachment level, and fill of the osseous defect.[20-24] Although guided tissue regeneration is a well-documented and beneficial regenerative surgical modality, it was excluded to avoid possible complex flap manipulations and risk of membrane infection.[25-27]

Soft tissue preservation and use of mattress sutures in the interdental papillary area ensured optimal isolation and protection of the regeneration site with minimal postsurgical gingival and interdental papillae recession. This was further ensured by slight releasing of the flap from the underlying periosteum and muscle attachments.

B. Orthodontic treatment performed only after periodontal regeneration enhances attachment gain and improves tissue contours.

To optimize the esthetic appearance of the periodontally inflamed and spaced maxillary anterior dentition, attention should be given to the use of advanced periodontal surgical methods and to the proper integration of the necessary orthodontic treatment. Tooth movement with active periodontal disease can accelerate attachment loss.[8,28,29] However, some clinicians still advocate initiation of tooth movement before periodontal surgery is carried out. They claim that tooth movement decreases volume of bone defect and increases the collective area of bony walls, thereby increasing the regeneration potential.[30,31] Yet, most clinicians to date advocate initiation of orthodontic treatment only after periodontal regeneration has been completed. This approach is based on previous clinical observations and research, as follows:

1. In deep pockets, non-surgical therapy will be inefficient in defect debridement and root decontamination.[18,32,33] This may deepen and widen the bony defect, especially during tooth movement.[8,28,29]
2. Closed interdental spaces result in narrow papillae that are difficult to manipulate during surgery and may become ineffective in maintaining full coverage of the implanted graft materials and the clot, thus compromising the healing process.[7,34]

3. A wide defect allows for improved surgical access for effective debridement and root-planing, and for decortications of surrounding bony walls to recruit bone-forming cells to the wound.
4. Crown and/or root approximation may push the interproximal and marginal tissues coronally and more effectively if implemented only after completion of regenerative therapy. This may result in creeping of marginal gingiva and gain in interdental papillae height.[9,10]

C. Orthodontic therapy should start early following periodontal regeneration.

Only limited data exist regarding optimal timing of tooth movement following bone grafting procedures. Some clinicians claim that early initiation of tooth movement (two to four weeks after the regenerative procedure) is advantageous due to reduced resistance to orthodontic forces, thereby shortening the orthodontic and overall treatment period.[10-14] However, others believe that tooth movement in early wounds may potentially stimulate osteoclastic activity, which will result in root resorption.[9] At this time, no short-term clinical or radiographic evidence exists to contradict the initiation of orthodontic treatment six weeks after the regenerative procedure as was carried out in the presented case. Regardless, care was taken to use only light orthodontic forces to minimize micro movements of the organizing blood clot and optimize the biologic conditions for periodontal regeneration.

D. Orthodontic intrusion of recessed teeth may help resolve bony defects and gingival coronal creeping.

Tooth intrusion following periodontal surgical therapy may enhance clinical attachment, providing biomechanical force system and oral hygiene are maintained.[35-37] This phenomenon is not completely understood, although two possible mechanisms have been suggested:

• The stretching of the periodontal ligament fibers at the marginal level generates a "natural filter," reducing the down-growth of epithelium.

• Orthodontic stimulation increases the turnover in the periodontal ligament, thereby improving the chances of periodontal ligament cells to repopulate the previously infected root surface.[35]

E. Root-coverage procedure performed only after teeth alignment is more predictable.

In the past, it has been argued that teeth with recessed or thin gingiva would indicate mucogingival grafting to precede orthodontic tooth alignment. It was believed that tooth movement inside, and even more outside, the alveolar bone envelope would cause further injury to the already stretched and vulnerable marginal tissues. Therefore, early root coverage was considered a preventive measure.[38,39] However, recently clinicians claim that root coverage prior to tooth movement is unnecessary for several reasons:

1. Controlled tooth movement would "bring" the bone with the tooth, and no further recession would likely occur. Thus, no change in prediction of maximum root coverage would follow.[15]
2. Gingival grafting would not guarantee resistance of grafted marginal tissue to mechanical or bacterial provocation that can occur during tooth movement. Therefore, the patient may be exposed to a second "round" of gingival grafting.[40,41]
3. In most cases, orthodontic treatment moves the roots back into the envelope of alveolar bone. This in itself may reduce marginal recession, and definitely provide better conditions for successful root coverage.[42,43]

F. The bilaminar approach using the triangular coronally advanced flap is preferred for isolated Class III recession defects.

In most cases with interdental crest and papilla loss, complete root coverage is unpredictable.[15,44] However, to maximize coverage, it is necessary to increase the width of a naturally thin gingiva by harvesting a connective tissue graft composed of dense connective tissue.[16,44-46] The use of the triangular-shaped advanced flap may contribute to effective nourishment of the grafted tissue, allow for easy and effective flap advancement with full protection of the graft, and decrease the probability of tissue scarring. Complete root coverage with gingiva of thick biotype, though non-predictable in Class III recessions, may still be achieved.[44]

Summary

Advanced periodontal and orthodontic treatment may result in the restoration of function to the periodontally involved dentition and in marked improvement in esthetics. The case presented demonstrates a gain in clinical attachment, radiographic evidence of bone fill, significant coronal creeping of the marginal gingiva, and almost complete reformation of the interdental papilla between the right maxillary central and lateral incisors. Therefore, it may be assumed that root approximation together with retraction and intrusion of the incisors collectively resulted in "excess" soft tissue, labially and interdentally, being pushed and stretched in a coronal direction. This may be predictably achieved when orthodontic movement begins early after periodontal regenerative treatment. However, the correction of gingival contours via root-coverage procedure may be more successful if implemented only after tooth alignment. This correct sequencing of clinical procedures in multidisciplinary treatment of a periodontally and esthetically compromised dentition is a key factor in achieving long-lasting functional and esthetic results.

Acknowledgment

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"This correct sequencing of clinical procedures in multidisciplinary treatment of a periodontally and esthetically compromised dentition is a key factor in achieving long-lasting functional and esthetic results."

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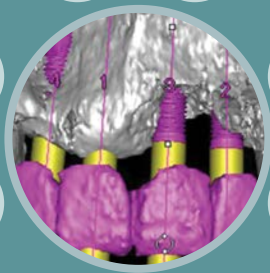

RESTORATION of Optimal Esthetics in Complex Clinical Situations

Using an Interdisciplinary Strategy in Combination with Advanced Techniques and Technologies in Regenerative Medicine

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The digital *jCD* version features a preview and link to an educational DentalXP video about this article.

Abstract
Patients often neglect or delay dental care for an extended time because of their negative experiences with and fear of dental treatments. This neglect may result in the advance of periodontitis with severe bone loss, a substantial number of missing teeth, and problems with the remaining teeth. Preexisting malocclusion can aggravate this condition. This case report demonstrates an interdisciplinary strategic approach, in combination with the use of biologically grounded, clinically proven, and viable techniques and technologies to restore optimal esthetics and function in such complex cases. The authors emphasize the importance of carefully planning the timing and sequence of performing periodontal, orthodontic, and implant therapies. The advanced techniques and technologies successfully implemented in this case report include the growth factor and titanium mesh (Ti mesh)-assisted bone augmentation; ovate pontic-mediated, noninvasive soft tissue contouring; and photofunctionalization of dental implants.

Key Words: advanced periodontal disease, orthodontic treatment, three-dimensional alveolar ridge augmentation, photofunctionalized implants, soft tissue remodeling technique

Introduction

Many patients tend to neglect or defer dental care for years because of their fear of and past negative experiences with dental treatments. This neglect may result in worsening periodontal disease with severe bone loss, substantial numbers of missing teeth, and misalignment of remaining teeth. Malocclusion can further complicate the condition, and escalated efforts are required to restore teeth. In this case report, the authors demonstrate that an interdisciplinary approach with implementation of biological and evidence-based advanced techniques and technology can mitigate such complex clinical situations and restore optimal esthetics and function.

Diagnosis

A 38-year-old female patient presented with severe, generalized chronic periodontitis. Tooth #1 was lost dues to caries; #19 and #30 had been extracted with advanced attachment loss. Bilateral mandibular second and third molars were mesially tilted and severe dental caries was noted in those areas. She had an Angle Class II, Division II malocclusion. Pathological migration of a number of teeth disrupted the integrity of the occlusal plane **(Figs 1 & 2)**.

Treatment Plan

Due to severe periodontal bone loss and dental caries, we planned to extract teeth ##7-10, #14, and #16 and restore them with dental implants. Teeth ##7-10, #19, and #30 would be replaced with dental implant-supported restorations. Orthodontic treatment was planned before implant placement to correct the occlusal plane; to reestablish an Angle Class I occlusion and canine-to-canine relation; and to secure adequate restorative space for ##7-10, #19, and #30.

Treatment

In all periodontally compromised situations, treatment begins with initial preparation. Before orthodontic treatment can begin, bleeding during probing must be eliminated through initial preparation. On occasion, it is necessary to use open flap debridement to achieve adequate infection control.

In this case, the extraction of #9 and #10 was intentionally postponed to provide the support for an orthodontic wire and an esthetic reference **(Fig 3)**. During orthodontic treatment, the patient underwent careful monthly monitoring and professional cleaning. After orthodontic treatment was completed, #9 and #10 were extracted.

Figure 1: The patient presented with severely compromised esthetics due to advanced periodontitis and dental caries. She had an Angle Class II, Division II malocclusion and a deep bite.

A diagnostic wax-up was made and duplicated into a radiopaque surgical stent. Two- and three-dimensional radiographic analyses indicated substantial volume of horizontal and vertical alveolar bone defect at the #9 and #10 areas **(Figs 4-7)**. Teeth #8 and #10 were selected for implant placement, and #7 and #9 were restored as pontics.

Esthetic implant restoration without tissue-color ceramics requires the elaborate planning and precise placement of implants, followed by careful maintenance and management of soft and hard tissues. Three-dimensional alveolar ridge augmentation was achieved by using a combination of autogenous bone and xenografts (Bio-Oss Cancellous 0.25-1.0 mm particles, Geistlich; Princeton, NJ) with the addition of a growth-factor-enhanced matrix (GEM21, Osteohealth; Shirley, NY). The growth factor-enhanced matrix consisted of recombinant human platelet-derived growth factor-BB and tricalcium phosphate. The addition of the growth factor in the graft materials has been demonstrated to be effective for successful vertical augmentation, particularly in challenging situations.[1-3] Bone graft materials were covered with a titanium mesh (Ti mesh) and collagen membrane **(Figs 8-10)**.

After eight months of healing, the Ti mesh was removed, and photofunctionalized implants were placed. Photofunctionalization is the chairside, rapid conditioning of dental implants to reactivate their biological capability. The principles and clinical effects of photofunctionalization are described elsewhere; briefly, photofunctionalization removes hydrocarbons from implant surfaces and regenerates hydrophilicity.[4-6] Photofunctionalized implants showed a strength of osseointegration three times greater than that of untreated implants in animal models and a rate of implant stability quotient three to 20 times faster increase per month in humans.[7,8]

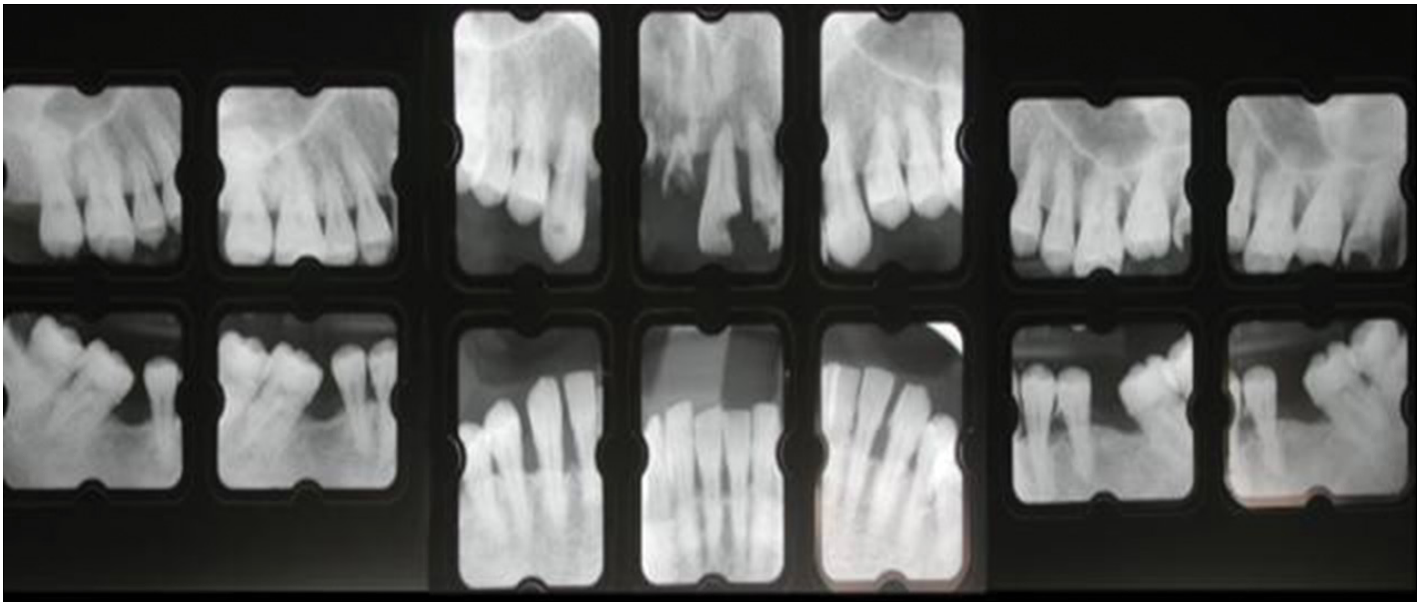


Figure 2: First visit x-ray. The patient had advanced alveolar bone resorption in her maxillary incisor area, and moderate alveolar bone resorption throughout the rest of her mouth.

Figure 3: Before removal of the orthodontic appliance, inflammation was found around #9 and #10. Although the teeth were in poor condition, they were useful for wire stabilization and space maintenance during orthodontic treatment.

Figure 4: The healed ridge showed a significant three-dimensional defect, lacking the ideal interdental papillae shape.

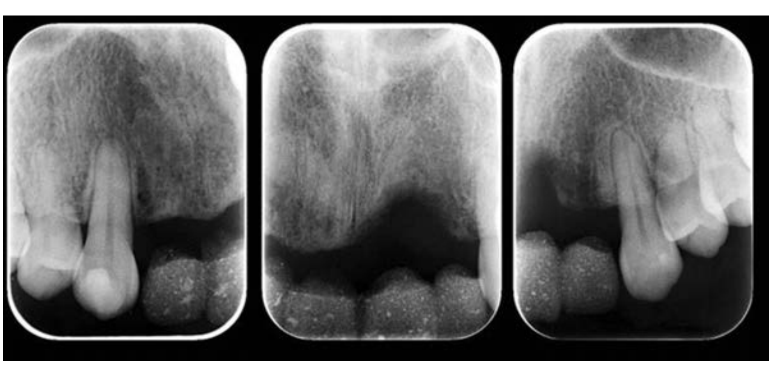
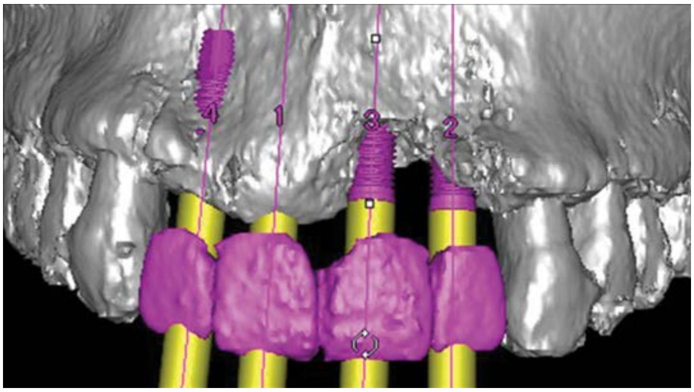
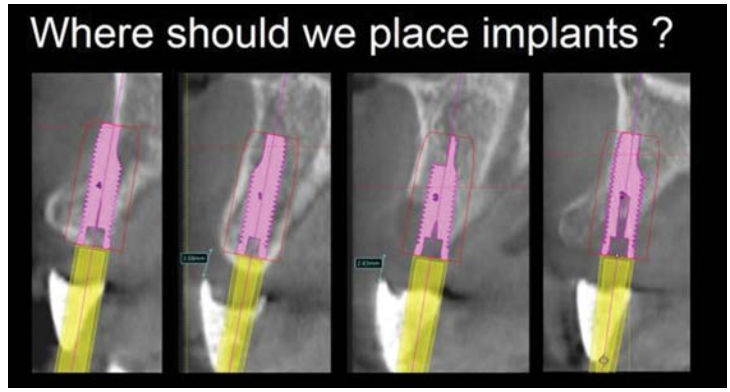


Figure 5: Periapical x-rays before augmentation showed a vertical bone defect around the #9 and #10 area.

"Many patients tend to neglect or defer dental care for years because of their fear of and past negative experiences with dental treatments."





Figures 6 & 7: Computer simulation indicated that #8 was the best option for ideal implant positioning. The #10 site was also selected for implant placement.

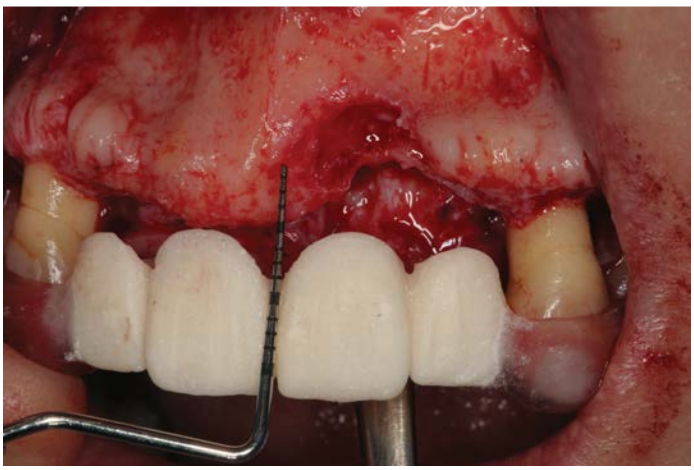


Figure 8: The actual alveolar bone defect was more severe than anticipated from the periapical radiographs. The mid-papilla area had a vertical defect as well.

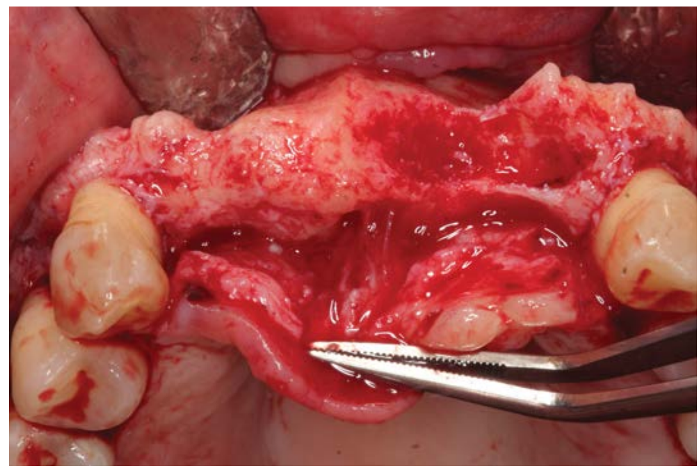


Figure 9: The left side of the site showed a significant horizontal defect.

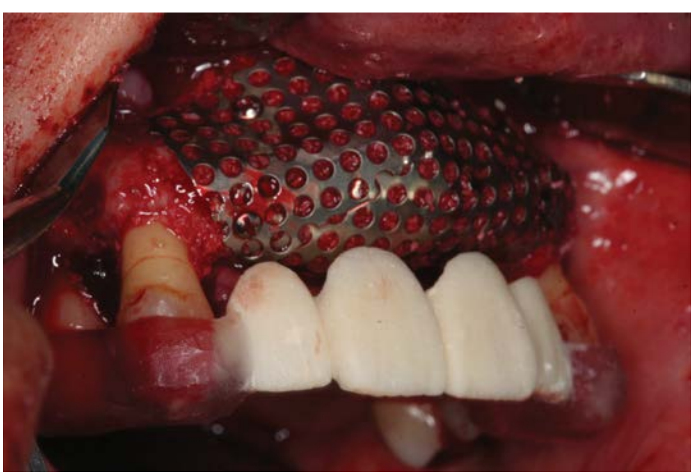


Figure 10: A 0.1-mm thick trimmed Ti mesh was slit and bent to match the desired regenerative form more accurately. The preliminary form of the mesh was designed and tested by using a surgical template.

"An interdisciplinary approach with implementation of biological and evidence-based advanced techniques and technology can mitigate such complex clinical situations and restore optimal esthetics and function."

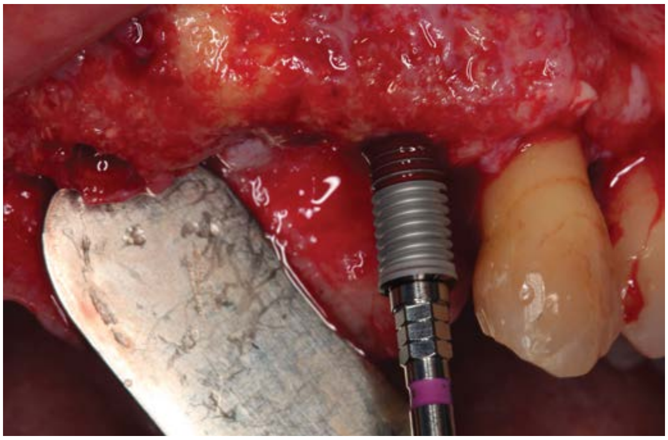


Figure 11: A photofunctionalized implant showed blood climbing up the implant surface.

Figure 12: After implant placement, additional bone augmentation was performed.

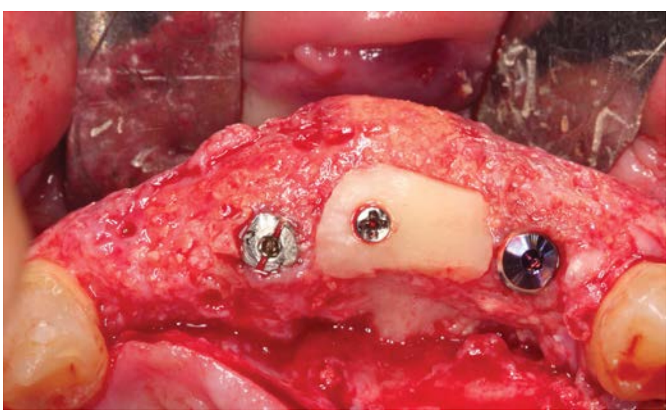


Figure 13: Guided bone regeneration with Ti mesh and resorbable collagen membranes resulted in a 3- to 4-mm thick horizontal buccal bone regeneration.

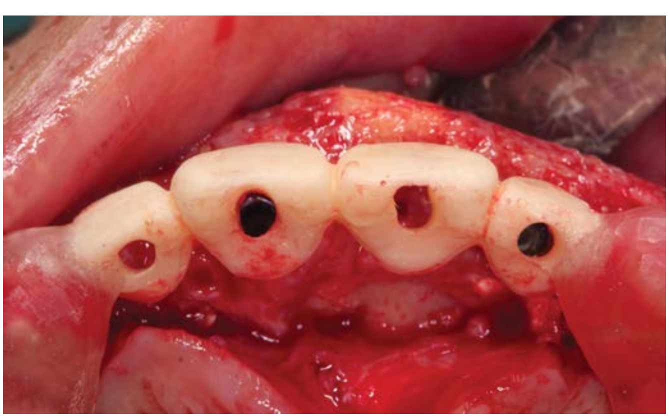


Figure 14: The mid-papilla supporting bone was successfully regenerated, as seen when the template is placed in position.

Photofunctionalization was performed by treating the implants with ultraviolet light for 15 minutes using a photo device (TheraBeam Affiny; Ushio; Tokyo, Japan). During placement, regenerated hemophilicity was confirmed as an improved physicochemical property after photofunctionalization **(Fig 11)**.

Additional ridge augmentation was performed during implant placement at the #8 site with a monocortical block **(Figs 12 & 13)**. An adequate volume of three-dimensional hard- and soft-tissue augmentation was clinically confirmed **(Fig 14)**. The soft tissue was contoured by using a noninvasive soft tissue remodeling technique.[9] The technique obviates surgical intervention and involves the use of ovate pontics to form the soft tissue gradually. Results in clinical cases demonstrated the usefulness of the technique for avoiding traumatic scar reaction after the second surgery and improving the final emergence profile and papillae formation. A temporary adhesion bridge with ovate pontics was prepared and placed prior to uncovering the implants. Over a three-month period, the pontic contour was adjusted five times to shape the soft tissue progressively **(Figs 15-18)**. A screw-retained provisional restoration was fabricated and placed.

After four months of patient observation, we took a final impression with custom-made impression copings. A zirconia-frame, all-ceramic, screw-retained final restoration was selected for optimal esthetic outcome and peri-implant tissue management **(Fig 19)**.

> "A patient who is periodontally susceptible is even more likely to develop peri-implant mucositis."

Figure 15: Compared with the defect shown in Figure 4, the ridge was successfully regenerated three dimensionally, before soft tissue remodeling. The soft tissue condition was esthetically adequate.

Figure 16: The adhesion bridge for guiding soft tissue remodeling.

Figure 17: The first stage of soft tissue remodeling was deepening, which was followed by widening.

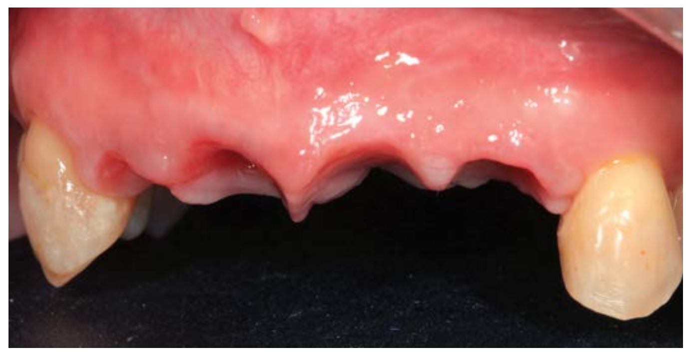


Figure 18: Soft tissue remodeling was almost complete.

Figure 19: The subgingival contour of the provisional restoration was easily transferred to a zirconia frame by using computer-aided design/computer-aided manufacturing.

Figure 20: The final result was that the bilateral canine relationship had improved to Angle Class I, with the correct overbite.

Finally, an implant-supported maxillary anterior restoration was in place with satisfactory esthetics and periodontal health. The patient also gained improved functional parameters, including the integrity of the occlusal plane, an Angle Class I canine relationship, solid posterior occlusion, and proper anterior guidance **(Figs 20-24)**.

The patient's self-care has been monitored carefully during the maintenance phase, and professional cleaning has been conducted at least once every month. This maintenance cleaning can be extended to once every three months if the patient shows evidence of proper self-care **(Fig 25)**.

Figure 21: A very natural appearance.

Figure 22: Final resting tooth display.

Discussion

Many dental problems are multifaceted; the timing and sequence of each phase of the treatment plan (periodontal, orthodontic, and dental implant procedures) greatly affect the final treatment outcome. Orthodontic[10,11] and dental implant treatments[12,13] should not be initiated if periodontal disease is not under control. In complex cases, orthodontic treatment often is not possible due to the lack of anchors. Although placing dental implants is an effective way to provide an anchor for orthodontic treatment in complex cases, implant placement prior to orthodontic treatment requires careful planning because, at this point, the location of the implant must correspond with an ideal position of the future restoration.[14,15] On the other hand, orthodontic treatment facilitates site development procedures prior to dental implant treatment, provides better management of restorative space, and increases the chance of better esthetic results.[16-18]

Figure 23: Our ultimate goal of a natural-looking smile, with a natural soft tissue profile and tooth superstructure matching the patient's overall appearance.

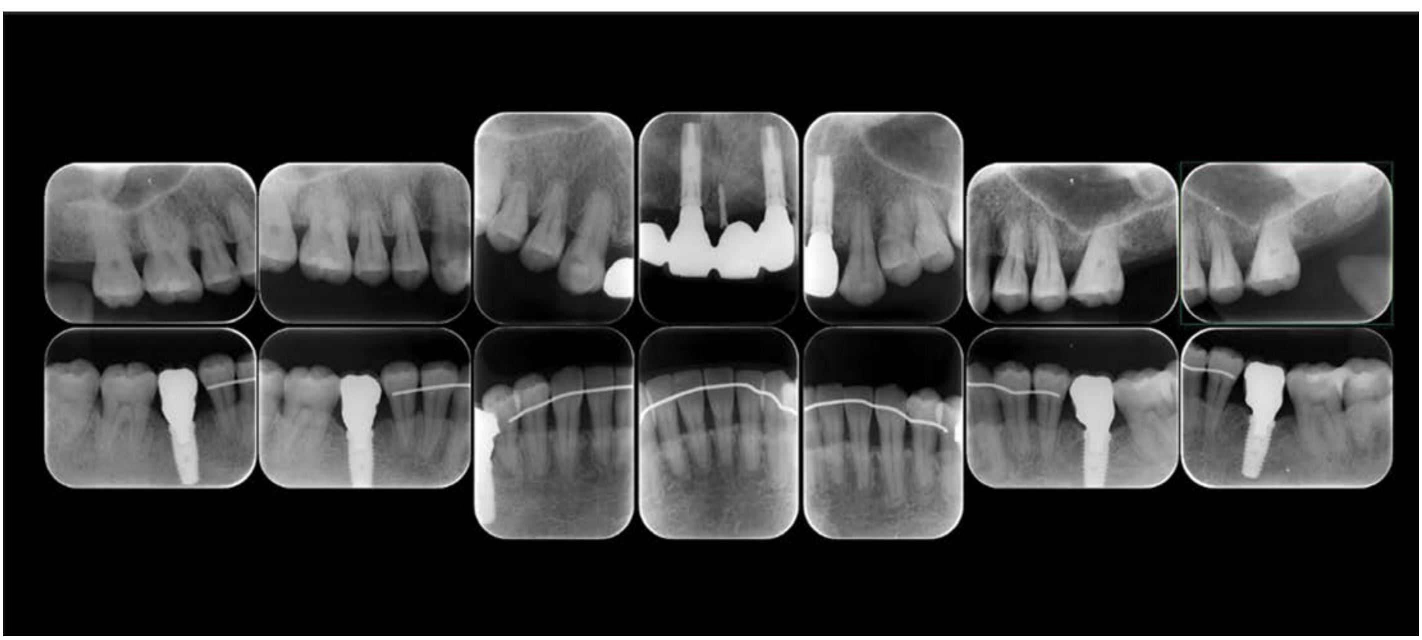


Figure 24: X-rays of the final condition.

Figure 25: The patient was instructed to use dental floss to achieve good plaque control.

In cases with multiple implant placements in the esthetic zone, we suggest the following strategies to achieve optimal esthetics:[19]

- consider immediate implant placement, if possible
- plan peri-implant tissue augmentation three-dimensionally
- place neighboring implants as distant as possible
- allocate pontics between implants effectively within biomechanical limits for better interdental tissue formation and stability
- consider using platform switching
- place implants in the native bone whenever possible
- reduce the number of abutment disconnections.

After we used those strategies, we selected the #8 and #10 areas as implant sites, because relatively greater volume of native bone was available **(Figs 6, 7, & 12)**. The enhanced osteoconductivity of photofunctionalized implants may also have contributed to the successful establishment of implant stability in such complex cases with compromised bone metabolic potential, as demonstrated in animal studies and evidenced in clinical studies.[7,8,20-22] Moreover, results from recent studies demonstrated that photofunctionalization is effective in improving the osteogenicity and bone quality around the implant neck and in maintaining the peri-implant marginal bone level.[22-24]

Esthetic implant restorations without tissue color ceramics require the elaborate planning and precise placement of implants, followed by careful management of soft and hard tissue. With bone augmentation, our goal was to achieve hard tissue augmentation to obtain the following:

- a line connecting the interproximal height of the bone of the healthy adjacent teeth
- a point within 4 mm from the interproximal contact point of the future restoration
- a point 2 to 3 mm coronal to an ideally placed implant platform.

These three requirements mutually correspond most of the time **(Fig 12)**. Horizontally, our goal was to have at least 2 mm of facial bone at the platform level beyond the ideally placed implant body **(Fig 13)**, with the buccal bone contoured more facially than the margin of the final restoration **(Fig 14)**.[25,26] To achieve these goals, we selected guided bone regeneration with a combination of Ti mesh, collagen membrane, bone graft, and growth factor. With this augmentation technique, our study demonstrated that a mean ± standard deviation bone augmentation of 8.6 mm ± 4.0 mm in height can be obtained and that 85.8% ± 25.6% of the existing defect in height was regained.[27] For an optimal esthetic outcome, the Ti mesh must maintain adequate three-dimensional form and be intimately adapted to the augmentation site. These requirements were confirmed during ridge augmentation surgery **(Fig 10)**.

Adequate thickness, color, texture, and consistency of soft tissue should be present before performing uncovering surgery, but soft tissue augmentation can be performed at the same time as the uncovering surgery. When soft tissue thickness becomes less than 2 mm around the implant, bone resorption may be likely in the future.[28] However, in this case, soft tissue thickness seemed adequate after bone augmentation, so additional soft-tissue augmentation was not necessary.

After an implant is uncovered, soft tissue shape can be guided by a series of provisional restorations by means of subgingival contour manipulation. This technique requires abutment disconnections, which may lead to unnecessary bone loss around the implant-abutment junction.[29,30] The number of abutment disconnections can be reduced by connecting a final abutment at the uncovering stage, although it is difficult to anticipate the depth of the margin of a final restoration with this technique. If the margin of a final restoration is placed deeper than 2 mm, the risk of peri-implant mucositis due to residual luting cement will be increased. A patient who is periodontally susceptible is even more likely to develop peri-implant mucositis.[31,32]

Vela and colleagues[9] reported a new protocol to create an esthetic soft tissue profile by using the pressure of ovate pontics. They augmented the soft tissue with a connective tissue graft first, then progressively compressed the tissue over the implant site with ovate pontics on the provisional restoration. The implant is uncovered only by pressure from the ovate pontic, and without surgery. They demonstrated that an ideal soft tissue profile could be created in a non-surgical manner. The protocol is particularly useful in creating a papilla shape between two adjoining implants.[9] In this case, implants and pontics were alternating, avoiding the adjoining placement of two implants. Papilla height between an implant and pontic is expected to be maintained higher than that between two implants.[33-35]

As for the prosthetic considerations in the present case, Angle Class I canine relationship was established, and overjet and overbite became normal **(Fig 20)**. Optimal tooth shape and gingival display were supported by ideally positioned implants and the surrounding tissue foundation was enabled by bone augmentation **(Figs 21-23)**. Screw-retained final restorations are removable and give easy access to the implant for maintenance if any problems arise. Easy access for patient home care also ensures the long-term stability of final outcomes **(Figs 19 & 25)**.

Conclusion

An interdisciplinary, strategic consideration in combination with evidence-based use of biologically grounded and clinically viable techniques and technologies was used to restore optimal esthetics in a complex case that involved multiple issues, including a number of missing teeth, advanced periodontitis with severe bone loss, and a corrupted dental arch and occlusal plane. The successful clinical outcome was achieved with remarkable esthetic and functional improvement. The authors emphasize the importance of careful planning of the timing and sequencing of periodontal, orthodontic, and implant therapies. The advanced techniques and technologies successfully implemented in this case report include growth factor and Ti mesh-assisted bone augmentation; ovate pontic-mediated, noninvasive soft tissue contouring, and photofunctionalization of dental implants.

Acknowledgment

The authors thank Kiyoshi Nakajima, CDT (KN Dental Laboratory; Hitachi, Ibaraki, Japan), for his excellent work on the final restoration.

Cases with Multiple Implant Placements in the Esthetic Zone

The authors suggest the following strategies to achieve optimal esthetics:[19]

- consider immediate implant placement, if possible
- plan peri-implant tissue augmentation three-dimensionally
- place neighboring implants as distant as possible
- allocate pontics between implants effectively within biomechanical limits for better interdental tissue formation and stability
- consider using platform switching
- place implants in the native bone whenever possible
- reduce the number of abutment disconnections.

Attaining Hard Tissue Augmentation

Esthetic implant restorations without tissue color ceramics require the elaborate planning and precise placement of implants, followed by careful management of soft and hard tissue. With bone augmentation, our goal was to achieve hard tissue augmentation to obtain the following:

- a line connecting the interproximal height of the bone of the healthy adjacent teeth
- a point within 4 mm from the interproximal contact point of the future restoration
- a point 2 to 3 mm coronal to an ideally placed implant platform.

Note: These three requirements mutually correspond most of the time.

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"The successful clinical outcome was achieved with remarkable esthetic and functional improvement."

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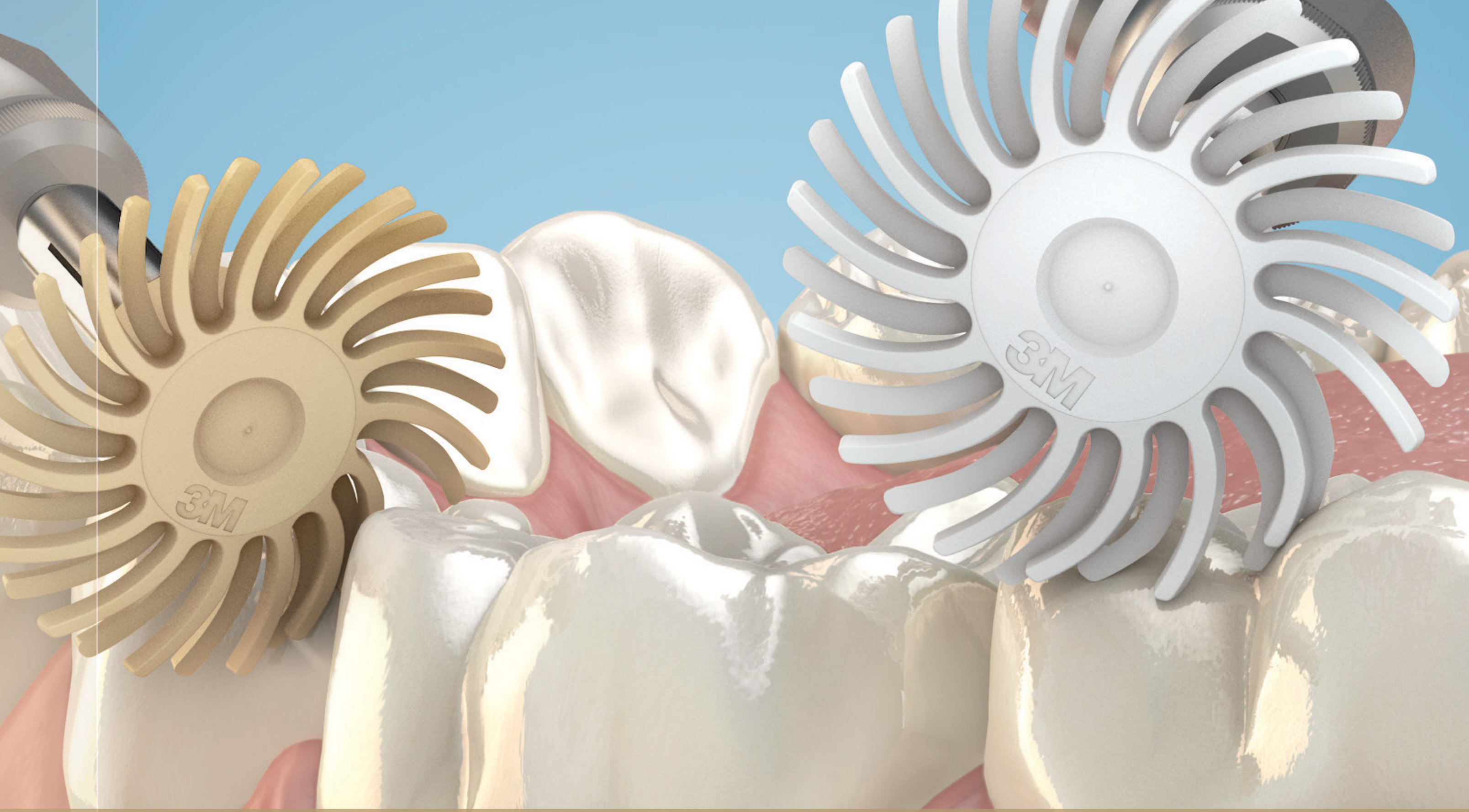

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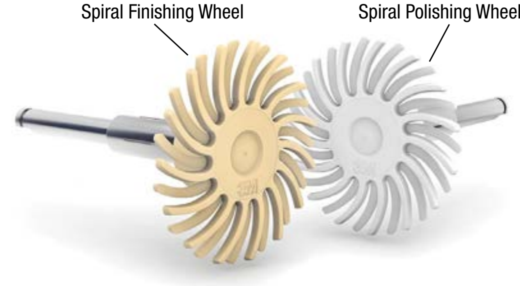

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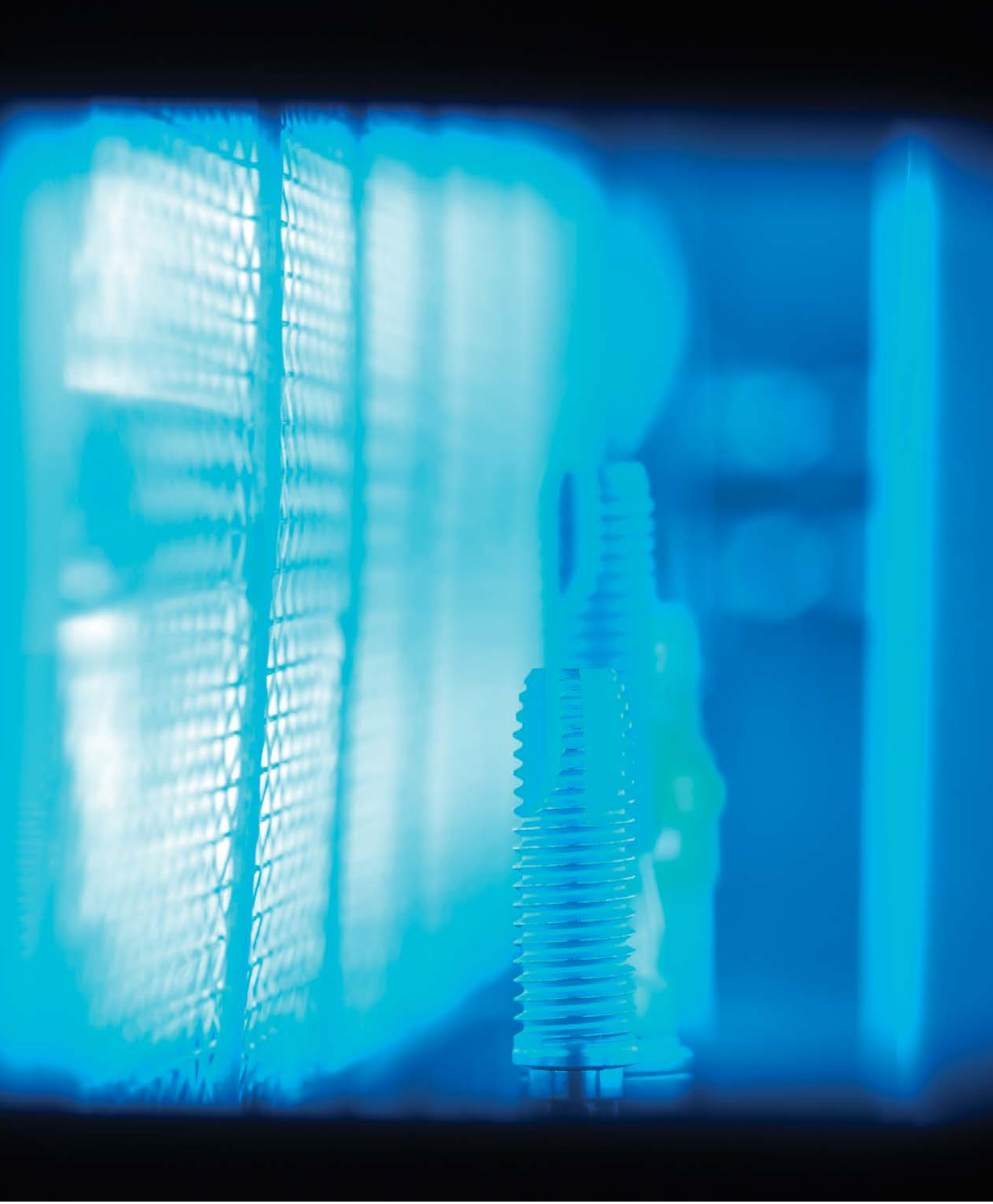

A Novel Strategy for Bone Integration and Regeneration: Case Studies

Photofunctionalization of Dental Implants and Ti Mesh

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The digital *jCD* version features a preview and link to an educational DentalXP video about this article.

Abstract

Ultraviolet light treatment of dental implants immediately prior to placement, or *photofunctionalization*, is a novel clinical tool with the potential to improve implant therapy. Photofunctionalization improves the surface properties of titanium surfaces by removing hydrocarbons, regenerating hydrophilicity, and optimizing electrostatic properties. We photofunctionalized dental implants and titanium mesh (Ti mesh) in two complex clinical cases requiring simultaneous guided bone regeneration, sinus elevation, immediate implant placement into the extraction socket, and esthetic consideration. The use of photofunctionalized implants and Ti mesh facilitated more strategic and aggressive treatment planning and resulted in successful treatment outcomes with secure application of immediate and early loading protocols. In vitro, the number of attached osteoblasts and the level of alkaline phosphatase activity were substantially increased on photofunctionalized Ti mesh, providing validation of the enhanced osteoconductive properties of photofunctionalized Ti mesh. An overview of the principles of photofunctionalization and practical guidance on its clinical use are presented. The clinical cases discussed here, along with the suggested technical guidance and research data, suggest that photofunctionalization is a useful and effective tool for improving implant therapy by enabling novel avenues of treatment and overcoming common challenges in current implant dentistry.

Key Words: photofunctionalized implants, UV, bone augmentation, Ti mesh, hydrophilic, osseointegration

Introduction

Ultraviolet (UV) light treatment of dental implants immediately prior to placement, known as *photofunctionalization*, has drawn considerable interest and attention as a novel and viable clinical tool for improving outcomes in implant therapy.[1-5] A significant number of implant cases require the site-development surgery to secure implant stability, obtain optimal esthetics, and ensure longevity. A common biological event for establishing osseointegration and pre-implant bone augmentation is the interaction between osteogenic cells and titanium materials. This article presents two clinical cases that successfully restored complex situations using photofunctionalized dental implants and titanium mesh (Ti mesh). Also presented are the theoretical and technical rationale for photofunctionalization and clinically relevant in vitro data that show an increased osteoconductivity of photofunctionalized Ti mesh.

Photofunctionalization

Dental implants are hydrophobic and covered with the hydrocarbons that always accumulate during normal aging **(Fig 1)**.[4-7] Photofunctionalization is the rapid, chairside conditioning of dental implants using UV light that results in the removal of hydrocarbons, regenerates hydrophilicity, and optimizes the electrostatic properties of the implant surfaces **(Fig 1)**.[4,8-10] The improved surface properties have been shown to enhance specific biological events necessary for osseointegration **(Fig 2)**. Photofunctionalization increases the strength of osseointegration threefold during the early stages of healing in animal models and results in an increase in bone-implant contact from 53% to 98.2%, virtually a maximal level of osseointegration.[8]

Specifically, photofunctionalization improves implant surfaces by (1) removing surface carbon that unavoidably accumulated on the surface during the biological aging of titanium, (2) regenerating superhydrophilicity that had been lost during the biological aging of titanium, and (3) optimizing the electrostatic status of the surface. Note that the presence of hydrophilicity alone does not improve the osteoconductivity of implants as significantly as when the three prerequisites of osseointegration are met.

In humans, a study involving a large number (90%) of complex cases showed that the healing time before functional loading was 3.2 months in photofunctionalized implants and 6.5 months in as-received implants.[1] There was no negative impact of the substantially accelerated loading on the success rate up to the follow-up period of 2.5 years. The speed of osseointegration, as evaluated by the implant stability quotient (ISQ) increase per month, is 3 to 20 times greater for photofunctionalized implants than as-received implants reported in the literature.[1,3] Clinical and animal studies reported the preservation, and in some cases even a gain, of the marginal bone level after receiving photofunctionalized implants.[2,11,12] The bone-implant interface at the marginal area was more intensively mineralized around photofunctionalized implants, suggesting that the quality of marginal bone was enhanced around photofunctionalized implants.[11] Photofunctionalization is effective for all the titanium surfaces tested, as shown by hydrophobic to hydrophilic surface changes of various dental implants **(Fig 1)**.[13,14] Hemophilicity, as shown by blood spiraling up the implant surface, can be seen around photofunctionalized dental implants as soon as they make contact with the implant site, in contrast to untreated controls **(Figs 3a & 3b)**.

Biological Validation of Photofunctionalized Ti Mesh

In addition to the acceleration and enhancement of bone-implant integration, the potential effect of photofunctionalization is to improve the interaction of biological cells and tissues with various biomaterials. Given the principle and mechanism behind photofunctionalization (i.e., carbon removable and hydrophilicity regeneration), photofunctionalization should be effective as long as the biomaterial is titanium- or titanium alloy-based. Among titanium-based biomaterials used in conjunction with implant therapy, Ti mesh could be a potential target of improvement because of its large area interfacing with existing and regenerating bone. Probably due to the improved biocompatibility, the anti-inflammatory effect of photofunctionalized Ti mesh is routinely experienced in clinical situations by the reduced manifestation of postoperative swelling and flare reaction, and the accelerated soft tissue wound healing. The percentage of post-implant surgery complications, including the chance of Ti mesh exposure, tissue dehiscence, and infection, can be reduced from 4.95% to 0.59% by applying photofunctionalization.[1] However, the potential effect of photofunctionalization to enhance the osteoconductivity of Ti mesh has not been examined, prompting us to perform the in vitro experimental study discussed in this report. Human mesenchymal stem cell-derived osteoblasts were cultured on Ti mesh with and without photofunctionalization using a previously established experimental protocol.[15] Photofunctionalization was performed for 15 minutes using a photo device (TheraBeam Affiny, Ushio; Tokyo, Japan). After 24 hours of culture, a greater number of osteoblasts attached on photofunctionalized Ti mesh than on untreated Ti mesh. As a result, an approximately five times greater area of Ti mesh was covered by osteoblasts, as seen in confocal microscopy images **(Fig 4a)**. In addition, the behavior of the cells was significantly improved. The cells were immunochemically stained for cytoskeletal actin (red) and adhesion protein, vinculin (green). A histogram showing the area of cell coverage (osteoblasts occupation in % area on Ti mesh) is also presented **(Fig 4b)**.

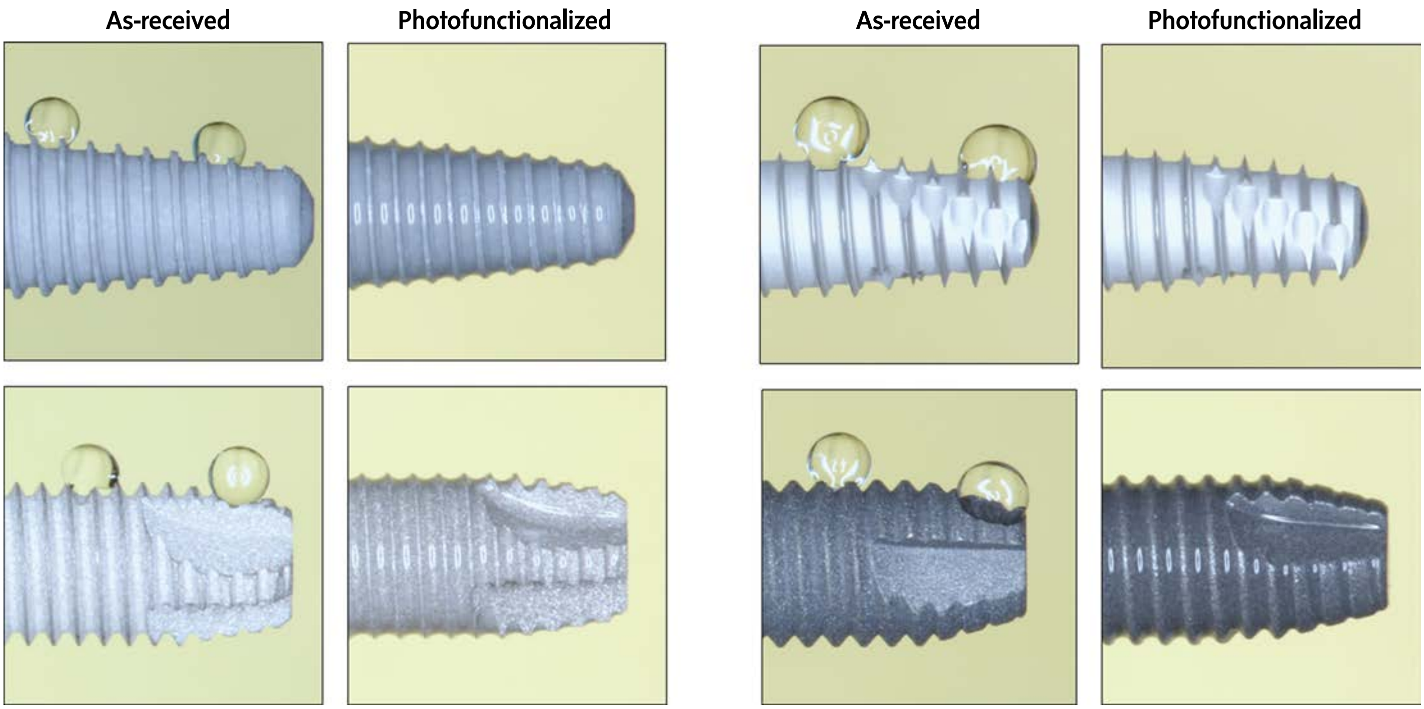


Figure 1: The rapid, chairside conversion from hydrophobic to hydrophilic surfaces on all commercial dental implants by photofunctionalization.

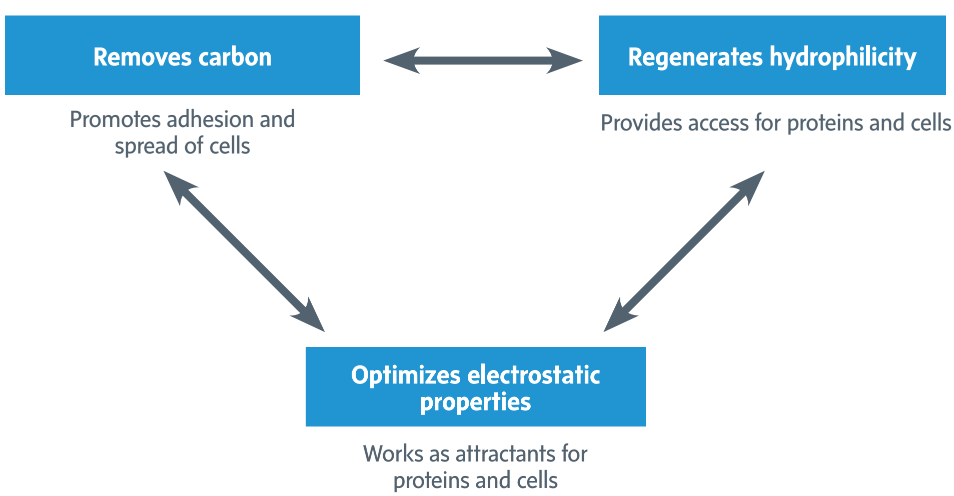
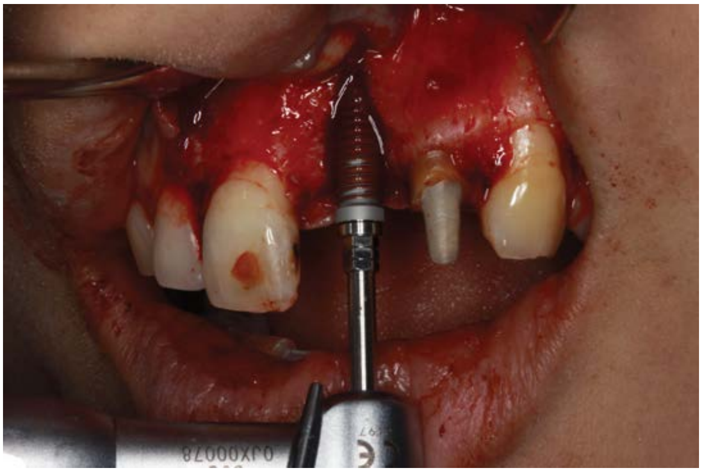
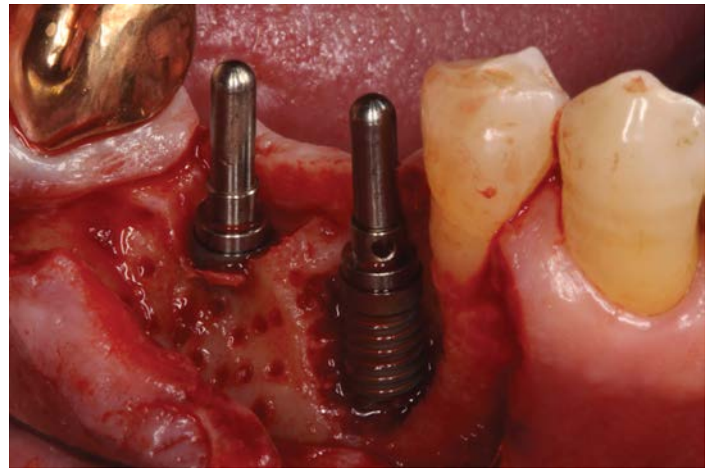


Figure 2: Photofunctionalization regains the prerequisites for osseointegration that have been lost or substantially compromised during biological aging of titanium.





Figures 3a & 3b: Typical clinical images depicting hemophilic surfaces of photofunctionalized dental implants.

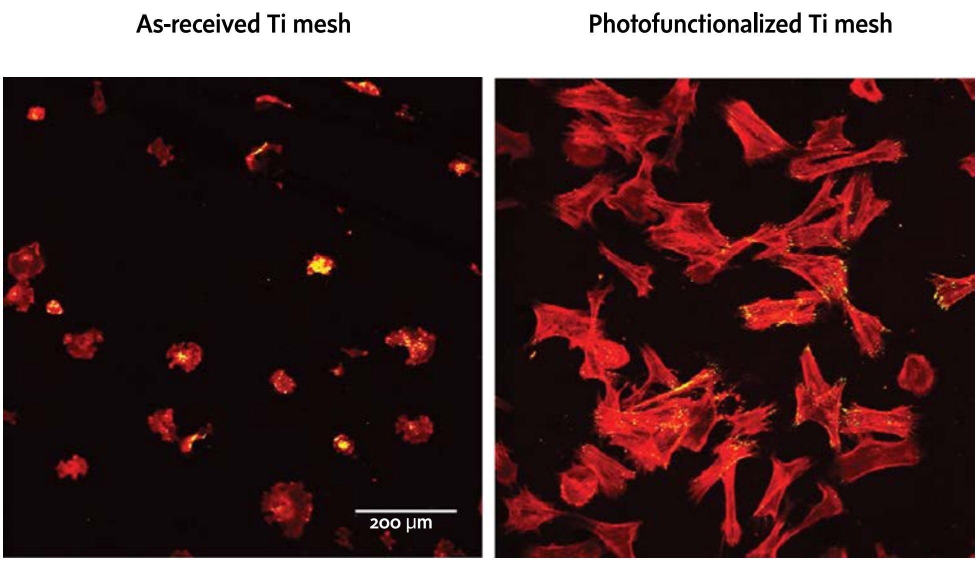


Figure 4a: Larger area of osteoblast coverage on photofunctionalized Ti mesh. Confocal microscopic image of human osteoblasts cultured on as-received Ti mesh and photofunctionalized Ti mesh 24 hours after seeding.

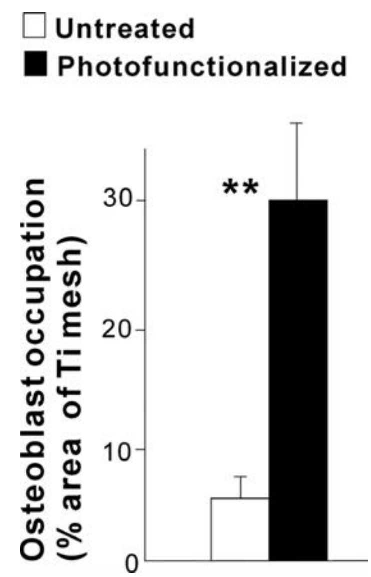


Figure 4b: Histogram showing the area of cell coverage (osteoblasts' occupation in % area on Ti mesh). **$p < 0.01$, statistically significant between as-received and photofunctionalized Ti mesh.

> "A common biological event for establishing osseointegration and pre-implant bone augmentation is the interaction between osteogenic cells and titanium materials."

The cells spread and settled more quickly on photofunctionalized Ti mesh, and there was increased expression of actin (a cytoskeletal protein) and vinculin (an adhesion protein) in cells on photofunctionalized Ti mesh **(Fig 5a)**. The results from cytomorphometry and protein expression densitometry are also presented **(Fig 5b)**.

Culture images after alkaline phosphatase (ALP) stain and the result from ALP chemical quantification are shown **(Figs 6a & 6b)**. The expression of ALP, an early marker of osteoblastic function, was considerably greater in cells on photofunctionalized Ti mesh. These results indicated that photofunctionalization of Ti mesh significantly increased the number of osteoblasts attached, enhanced the adhesion and retention of cells on Ti mesh, and expedited the osteogenic function in the cells.

Case Reports

Case 1: Fixed Implant Restoration with Simultaneous GBR in the Esthetic Zone Using Photofunctionalized Implants and Ti Mesh

Securing three-dimensional shape of bone and soft tissue (e.g., contour, height, and thickness) holds a key to successful implant restoration in esthetic cases.[16-18] A 46-year-old female presented with a dislodged bridge and root fractures in the anterior maxilla. Two months after teeth #7 and #9 were extracted, photofunctionalized implants (4 mm in diameter and 13 mm in length, Osseotite Certain, BIOMET 3i, West Palm Beach, FL) were placed at these sites. Photofunctionalization was performed by treating the implants with UV light for 15 minutes **(Fig 7a)**, using a photo device (TheraBeam Affiny) at chairside immediately prior to implantation **(Fig 7b)**. Simultaneous guided bone regeneration (GBR) was performed

> **"Photofunctionalization increases the strength of osseointegration threefold during the early stages of healing in animal models and results in an increase in bone-implant contact from 53% to 98.2%, virtually a maximal level of osseointegration."**

As-received Ti mesh | **Photofunctionalized Ti mesh**

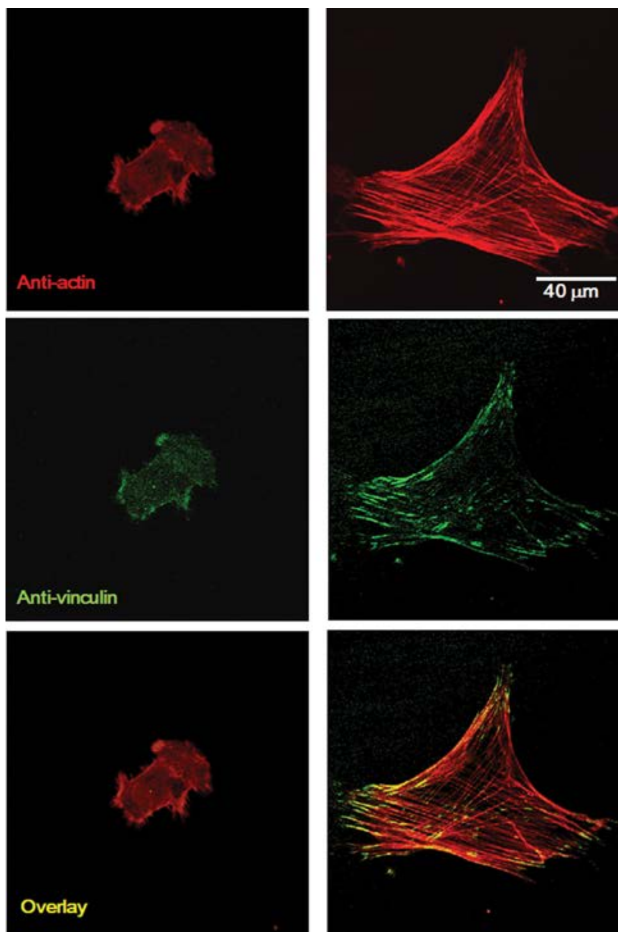


Figure 5a: Attachment and spreading behavior of human osteoblasts enhanced on photofunctionalized Ti mesh. High magnification confocal microscopic images are shown with immunochemical stain for cytoskeletal actin (red) and adhesion protein, vinculin (green).

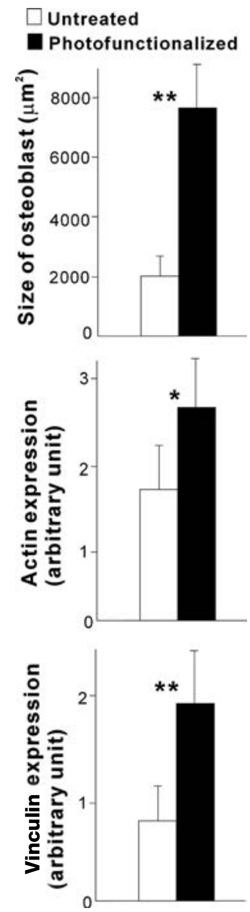


Figure 5b: The results from cytomorphometry and protein expression densitometry based upon the analyses using the microscopic images. *p < 0.05; **p < 0.01, statistically significant between as-received and photofunctionalized Ti mesh.

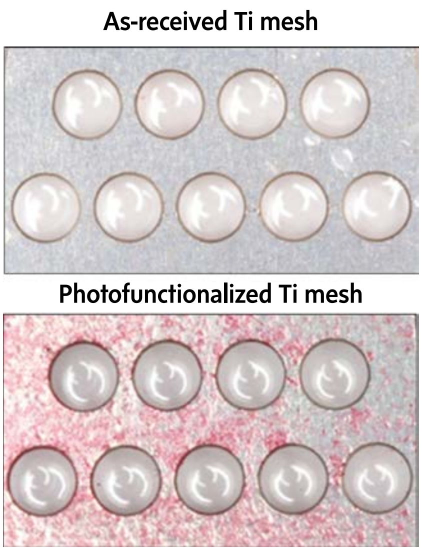


Figure 6a: Culture images after ALP stain and the result from ALP chemical quantification.

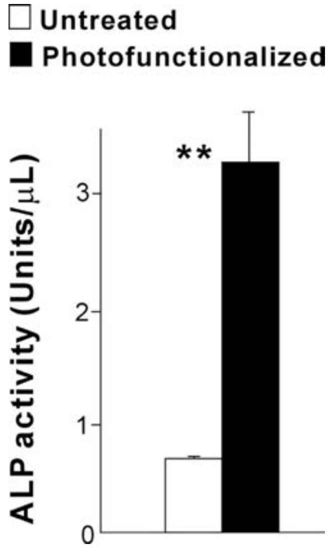


Figure 6b: ALP activity in human osteoblasts compared between as-received and photofunctionalized Ti mesh. **p < 0.01, statistically significant between as-received and photofunctionalized Ti mesh.

using Ti mesh, which was also photofunctionalized and confirmed to be highly hydrophilic **(Fig 8)**. After the Ti mesh was fixed with a cover screw, the defect was filled with xenograft bone substitute material (Bio-Oss Cancellous 0.25–1.0 mm particles, Geistlich; Princeton, NJ) and covered with resorbable collagen membrane (Ossix, OraPharma, Warminster, PA). After four months of healing, mature bone formation of sufficient width and height was confirmed clinically and a connective tissue graft procedure performed. Pre- and postoperative clinical images are presented in **Figures 9a-9c**.

The soft tissue healed for two months before the provisional restoration was placed **(Fig 10a)**.[19] Tooth #8 was saved as a submerged root to maintain the surrounding alveolar bone The final fixed restoration was placed, and the esthetics and function have been maintained satisfactorily after a one-year follow-up **(Figs 10b & 10c)**.

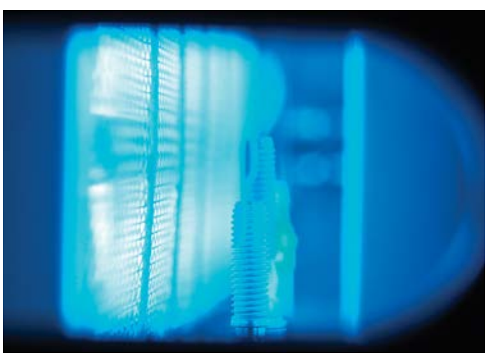


Figure 7a: UV light.

Figure 7b: A photo device used for photofunctionalization. The device provides an automatic 15- to 20-minute program of conditioning with optimized wavelength and strength of UV light treatment.

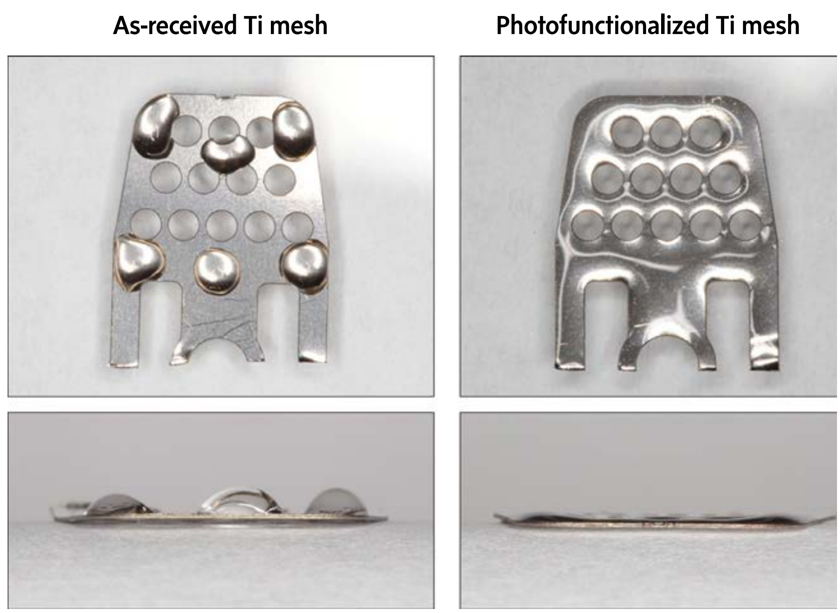
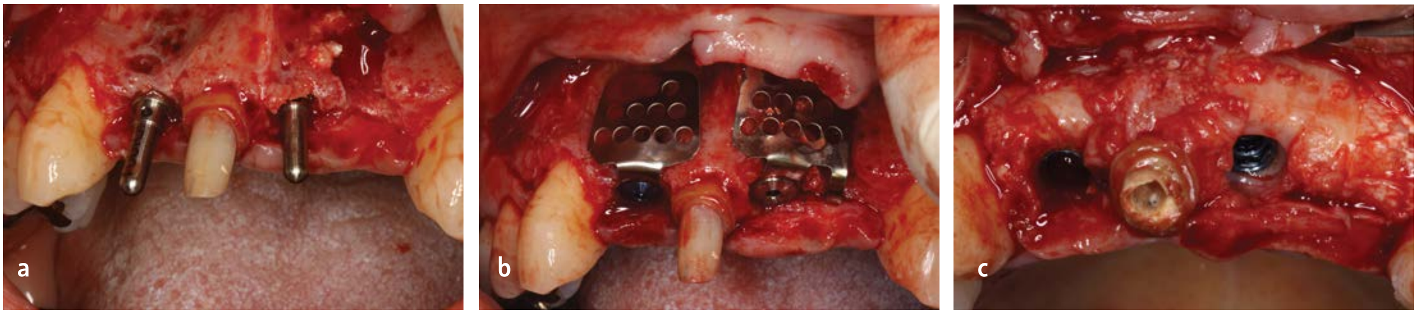


Figure 8: Hydrophobic-to-hydrophilic conversion of Ti mesh after photofunctionalization.



Figures 9a-9c: Case 1, clinical images during (a) implant placement and (b) simultaneous GBR using Ti mesh. The implants and Ti mesh were photofunctionalized. Note the matte Ti mesh surface due to widespread blood, as opposed to a glossy surface typically seen on as-received Ti mesh (b). Mature bone formation of sufficient width and height along with osseointegration were clinically confirmed after four months (c).

Figure 10a: Final restoration in place.

Figures 10b & 10c: A radiographic image of the final restoration along with the peri-implant x-ray image in Case 1.

"The use of photofunctionalized implants and Ti mesh enabled more strategic and aggressive treatment planning and resulted in successful treatment outcomes with secure application of immediate and early loading protocols."

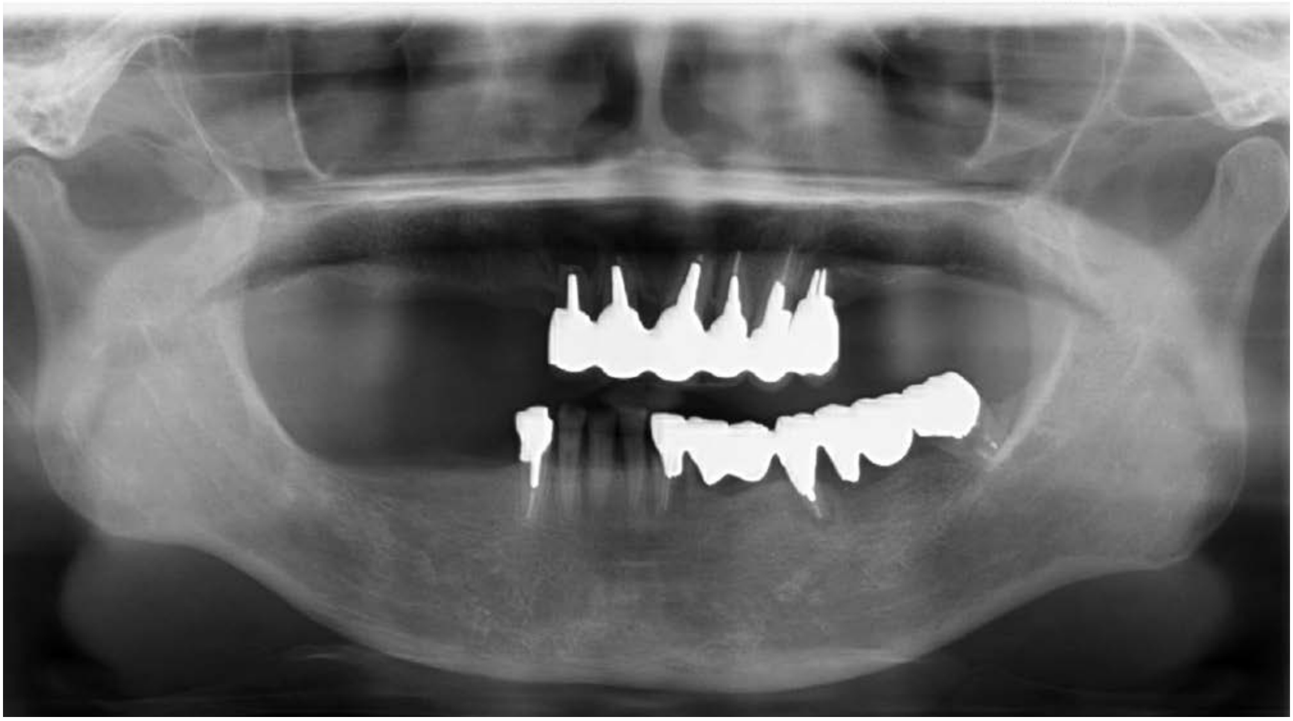
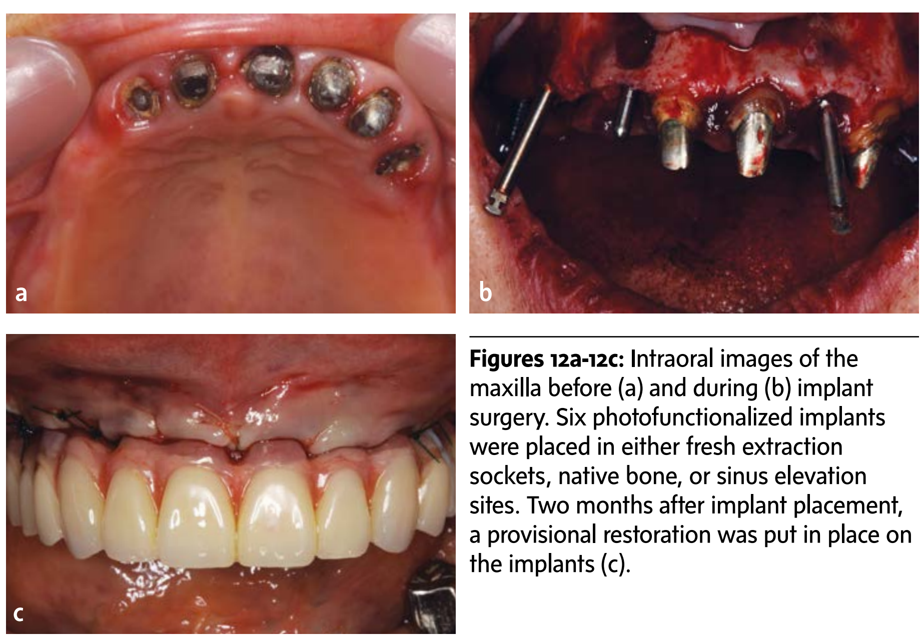


Figure 11: Case 2, panoramic x-ray image.

Case 2: Effective Application of Immediate and Early Loading Protocols on Photofunctionalized Implants

A 64-year-old female wearing upper and lower removable dentures presented for possible replacement with implant restorations **(Fig 11)**. A bone-anchored bridge with pink porcelain was planned for both the maxilla and mandible, and the application of early and immediate loading protocols was planned for the maxilla and mandible, respectively. A two-stage extraction was planned for the six maxillary hopeless teeth; three teeth were extracted on the day of implant placement, while the other three were extracted when the provisional restoration was placed onto the implants **(Fig 12a)**.

After the three maxillary teeth were extracted, six photofunctionalized implants (4 mm in diameter and 13 mm in length, Osseotite Certain) were placed; two implants were placed in fresh extraction sockets at the bilateral



Figures 12a-12c: Intraoral images of the maxilla before (a) and during (b) implant surgery. Six photofunctionalized implants were placed in either fresh extraction sockets, native bone, or sinus elevation sites. Two months after implant placement, a provisional restoration was put in place on the implants (c).

lateral incisor areas, while two implants were placed in the bilateral premolar areas with native bone support **(Fig 12b)**. Another two implants were placed in the posterior maxilla with simultaneous sinus elevation, using the lateral window technique. A temporary prosthesis was placed using the three natural teeth as anchors while the implants were kept unloaded. After two months, the implants were uncovered and the provisional restoration was screwed onto the six implants at the time of extraction of the remaining three teeth **(Fig 12c)**. Two months later, all remaining teeth in the mandible were extracted and four photofunctionalized implants were placed (all were 4 mm in diameter and 13 mm in length, except for the one at the lower right anterior position, which was 5 mm in diameter and 13 mm in length) **(Fig 13a)**. The implants were immediately loaded with a full-arch acrylic temporary prosthesis **(Fig 13b)**. After confirming successful osseointegration and soft tissue healing **(Fig 14)**, a computer-aided design/computer-aided manufacturing (CAD/CAM)-assisted final restoration was fabricated and placed **(Fig 15)**.

Figures 13a & 13b: Mandibular images before (a) and after (b) implant placement. Four photofunctionalized implants were placed and immediately loaded with full-arch acrylic provisional (b).

Seven Tips for Photofunctionalization

The results of the previous studies and the outcomes of the two cases discussed here show that photofunctionalization is a novel and effective tool that has the potential to improve multiple aspects of current implant therapy. The ability to overcome biological aging, a simple chairside procedure, and its versatile application are additional benefits of the technology. Its use need not be limited to expediting and enhancing osseointegration, but can also be extended to enhancing bone formation around Ti mesh. Here are seven practical tips for the effective use of photofunctionalization:

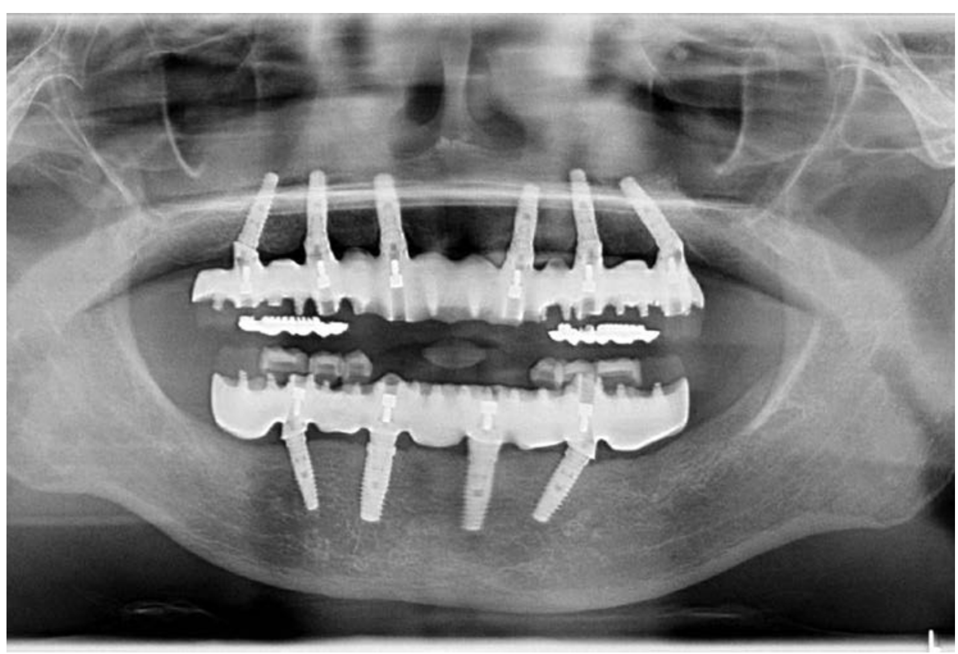


Figure 14: Panoramic x-ray image confirming successful osseointegration.

1. Photofunctionalization requires adequate conditioning (15 to 20 minutes for TheraBeam Affiny). Therefore, implants of appropriate diameter and length need to be selected prior to commencing surgery.

2. The use of one-step shorter implants (e.g., 10 mm instead of 11.5 mm) may be considered to make surgery less invasive due to improved osseointegration of the photofunctionalized implants.

3. When there is uncertainty about the size and length of implants to be used in the surgery, multiple potential implants should be photofunctionalized in preparation for the final decision.

4. The same number of implant drivers as implants need to be ready, to allow the implants to stand in the photo device **(Fig 16)**.

5. After photofunctionalization is complete, the implant and implant driver need to be handled and set in the handpiece with caution, and care should be taken not to drop the implant or make contact with unsterilized instruments or materials.

6. After photofunctionalization, the implants should be placed immediately (and certainly within 30 minutes) for maximal surface bioactivity. If the implants were stored without opening the photo device, the bioactivity appears to be maintained up to two hours. Therefore, if multiple implants are to be placed, the timing and sequence of implant placement and concomitant surgery need to be planned in advance. For example, if implants are to be placed in the maxilla and mandible with simultaneous GBR, photofunctionalization should be performed separately for the maxillary and mandibular implants.

7. Pay particular attention to the details of the fundamentals and principles of implant surgery. In particular, make sure that the implant site is filled with blood so that the photofunctionalized implant absorbs blood effectively and efficiently. Be sure to avoid contact of implants with saliva or contaminated tissues and fluids, which might dilute blood or cause biological and chemical contamination.

Figure 15: Presentation of the final prosthesis.

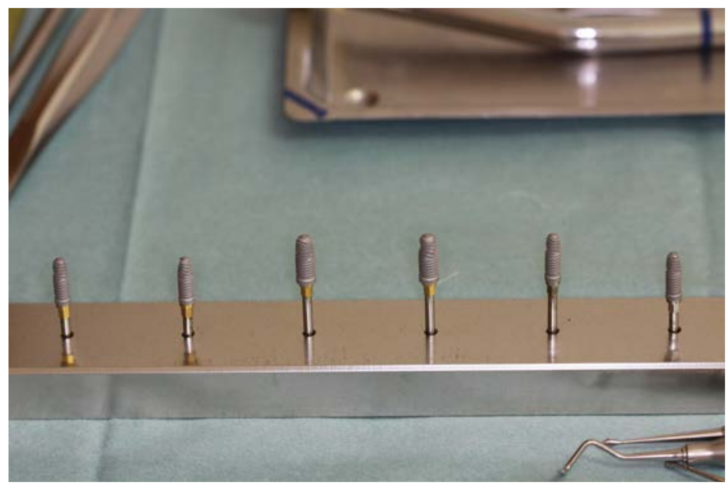


Figure 16: Dental implants with an implant driver set on a removable metallic stand. The stand will be placed in the photo device for photofunctionalization.

Summary

Ultraviolet light treatment of dental implants immediately prior to placement, or photofunctionalization, is a novel clinical tool with the potential to improve implant therapy. Photofunctionalization improves the surface properties of implant surfaces by removing hydrocarbons, regenerating hydrophilicity, and optimizing electrostatic properties. We first tested the effect of photofunctionalization to potentially enhance the osteoconductivity of Ti mesh in an in vitro culture study using human osteoblasts. The results showed that the attachment, spreading behavior, adhesion, and function of osteoblasts were remarkably increased on photofunctionalized Ti mesh compared to untreated ones, suggesting the considerable enhancement of osteoconductivity by photofunctionalization. We then applied photofunctionalization to dental implants and Ti mesh in two complex clinical cases requiring simultaneous GBR, sinus elevation, immediate implant placement into the extraction socket, and esthetic consideration. The use of photofunctionalized implants and Ti mesh enabled more strategic and aggressive treatment planning and resulted in successful treatment outcomes with secure application of immediate and early loading protocols. The cases discussed here, in combination with the results from human cell study, help to show that photofunctionalization is a useful and effective tool for improving implant therapy and that, with the advent of this technology, novel avenues of treatment can be pursued and some clinical challenges overcome. Long-term controlled trials and/or histologic studies are warranted to verify that photofunctionalization is a clinically significant and beneficial therapy.

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Esthetic and Functional REHABILITATION: A Case Report

Recreating a Patient's Smile

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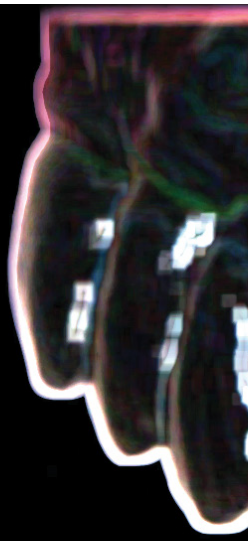
Bogdan Mykhaylyuk, DT
Myroslav Solonko, DMD, MSc

The digital *jCD* version features a preview and link to an educational DentalXP video about this article.



Abstract

Most people want to look beautiful. The ability to express feelings is fundamental to the quality of life, but expressing emotions is impossible without the freedom to smile.

A patient with an ill-fitting removable denture and a fixed, porcelain-fused-to-metal bridge sought care to improve her smile. This fixed bridge was removed and direct provisional restorations placed, followed by crown-lengthening surgery and implant placement, waiting 10 months for the patient to heal. We waited one month to check occlusal stability and patient satisfaction and then made the final precision impressions and master casts. We cemented the final restorations; lithium disilicate allowed the creation of an esthetic result without sacrificing strength with use of both full-anatomy and layered techniques. Dental implants make it possible to have non-removable teeth that can be integrated esthetically and functionally, allowing the recreation of tooth color, form, and structure to reestablish a patient's smile.

Key Words: microscope, implants, rehabilitation, transfer individualization, soft tissue management

"Use of magnification provides more precise performance during surgical interventions with the use of fine microsurgical instruments and suturing materials."

Introduction

Much of dentistry today is about visual control during treatment. More and more we realize that it is impossible to treat what we cannot see, and it does not matter whether we are dealing with one tooth or a complex case. Macroanalysis of the face must be followed by microanalysis in the patient's mouth, and we must pay attention to the smallest of details. Our eyes have limits, and even with excellent eyesight, we cannot perfectly see things such as the fit of restorations, margin surfaces after preparation, cracks, and many other details that can play a big role in the treatment plan. This is why it is important to use magnification during all treatment steps.[1]

We do not have to be impossibly precise, but we must try to avoid mistakes to get the best possible result. The main issue in this case was to recreate the patient's smile.

Microsurgical techniques are becoming increasingly important in periodontal and dental implant surgery. Use of magnification provides more precise performance during surgical interventions with the use of fine microsurgical instruments and suturing materials.[2,3] This precision reduces surgical trauma and allows better approximation of wound margins, which allows for more predictable wound healing.[4,5]

Use of dental implants for replacing missing teeth in posterior regions has become a standard treatment that yields high tooth survival and success rates during long-term observation.[6-9] However, thorough restorative-driven treatment planning is a prerequisite for a successful outcome.[10,11]

Case Presentation

The patient was a 57-year-old theater actress. Her chief complaint was that she was unhappy with her removable denture. She could not smile sincerely because of the esthetics, and she had functional problems while eating—chewing required much effort. She felt uncomfortable, and using the removable denture was too troublesome, so she stopped using it **(Figs 1 & 2)**.

The patient had undergone dental treatment five years previously. After the treatment was finished, the patient had a new fixed, porcelain-fused-to-metal (PFM) bridge and a removable denture with interlocking components. She was not happy with the way she looked, did not like her smile, and lacked self-confidence **(Fig 3)**.

Diagnostic Findings

Extraoral and Facial Findings

The vertical dimension of occlusion and lower third of the patient's face were lowered. The patient had an asymmetric facial appearance due to the loss of lip support, mainly on the buccal corridors. She had a medium smile line, showing 80 to 100% of the papillae. The gingiva around the PFM bridge was inflamed, with some bleeding on probing **(Figs 3 & 4)**.

Temporomandibular Joint and Mandibular Range of Motion

The patient had a normal range of motion and no joint sounds at external palpation. There was no muscle tenderness and no pain on opening or with lateral movement. Manipulation was easy, and the range of motion was within normal limits. There were no signs or symptoms of temporomandibular disorders.

Intraoral Findings

The patient had a PFM bridge and long proximal contact areas on the anterior teeth. There was a violation of biologic width that caused bleeding and inflammation. The dentogingival complex was, on average, 3 to 4.5 mm.[1-3] The tooth proportion was inadequate; the central incisors were 8 to 9 mm long, so there was no harmony in the patient's smile.

Dental Findings

All of the patient's maxillary teeth were missing except for ##7-10. She also had gingival inflammation, and her teeth had little mobility as a result of functional overload. In general, however, her prognosis was excellent.

Treatment Plan

The treatment plan began with a pretreatment interview and photographic series. The patient was given oral hygiene instructions.

Maxillary and mandibular casts and centric relation records were obtained and we performed facebow transfer and diagnostic wax-up planning. We removed the old PFM fixed partial denture and corrected the margin of preparation.

Direct provisional restorations were placed, followed by crown-lengthening surgery and implant placement, after which we waited 10 months for the patient to heal.

The laboratory technician produced a second set of provisional restorations. We waited one month to check occlusal stability and patient satisfaction. Then the final precision impressions were made, leaving the final esthetics and function to the laboratory technician, who fabricated the master casts. We cemented the final lithium disilicate restorations, gave the patient her nighttime appliance, and advised her concerning periodontal maintenance.

Figure 1: Initial portraits.

Figure 2: Initial profile portraits.

Figure 3: Maximum smile analysis.

Figure 4: Intraoral view shows inflammation and imprecise fit.

Clinical Procedure

Implant Positioning

After all the data were gathered, we started by removing the old PFM bridge and improving the margin of preparation.[12] Using a microscope at every stage of the treatment guaranteed better visual control and greater precision **(Fig 5)**.

Three-dimensional implant positioning plays a crucial role in the success of prosthetic restorations so that they meet all functional, hygiene, and esthetic requirements. Therefore, a diagnostic wax-up was prepared and a radiographic stent was fabricated by using flowable composite (Latelux, Latus PE; Kharkov, Ukraine) as a radiopaque material. After cone-beam computed tomography (CBCT), a radiographic stent was modified into a surgical template; this allowed for intraoperative visualization of the planned reconstruction and was used as a reference for implant positioning **(Figs 6 & 7)**.

The results of the CBCT study of the edentulous ridge in the distal maxilla revealed adequate bone height and width for uncomplicated and predictable implant placement. However, bucco-lingual reduction of the ridge width was visible in the regions of the canines and first premolars. Therefore, it was decided to place implants in the regions of the canines, second premolars, and first molars and to fabricate pontics in the region of the first premolars. Because of severe angulation of the alveolar ridge in relation to the prosthetic axis of #11, it was decided to place the implant in a restorative-driven position, which would result in apical fenestration of the buccal bone.

Implant Insertion

For implant insertion, a full-thickness flap was raised by using a crestal incision in the edentulous area, and the incision was extended through the sulcus of the adjacent teeth. Six dental

Figure 5: Removal of old PFM bridge reveals the amount of cement in the papillary zone.

Figure 6: Surgical guide created by means of wax-up.

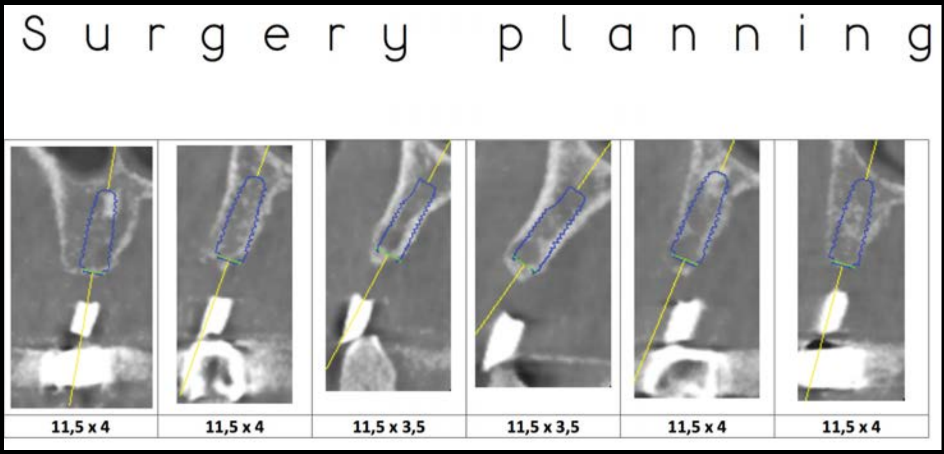


Figure 7: Digital CT planning of implant placement.

implants (U-Impl Switzerland GmbH; Biel/Bienne, Switzerland) were placed in the positions of #3, #4, #6, #11, #13, and #14. A guided bone regeneration procedure was performed by using deproteinized bovine bone mineral (Bio-Oss, Geistlich Pharma AG; Wolhusen, Switzerland) as well as collagen membrane (Bio-Gide, Geistlich Pharma AG) to close the fenestration defect. Autogenous bone chips collected from the drill during implant bed preparation were placed as a first grafting layer and subsequently covered with deproteinized bovine bone mineral particles. Healing abutments were placed, and the wound was sutured according to a non-submerged protocol.[13] Surgical crown lengthening was performed in the region of ##7-10. We used non-absorbable 5-0 synthetic monofilament suturing material (Seralene, Serag-Wiessner GmbH; Naila, Germany). A standard postoperative regimen was prescribed; this included antibiotic prophylaxis with amoxicillin (Amoxil, Arteriurn Corp.; Kyiv, Ukraine) for five days, analgesics to control postsurgical pain (Nimesil, Corp. Group; Berlin, Germany), as well as 0.2% chlorhexidine digluconate (Paroguard, Hager & Werken GmbH & Co KG; Duisberg, Germany) rinse twice a day for plaque control. Postoperative wound healing was uneventful. Sutures were removed after 10 days **(Figs 8-11)**.

Provisionals

After 10 months everything had healed, and it was possible to continue with the procedures **(Fig 12)**. In this patient's treatment, the margin was set to 0.3 mm below the free gingival margin. A conventional method for taking impressions was used for the implants and adjacent tissues.

Figure 8: Surgical guide fabricated on the basis of the diagnostic wax-up.

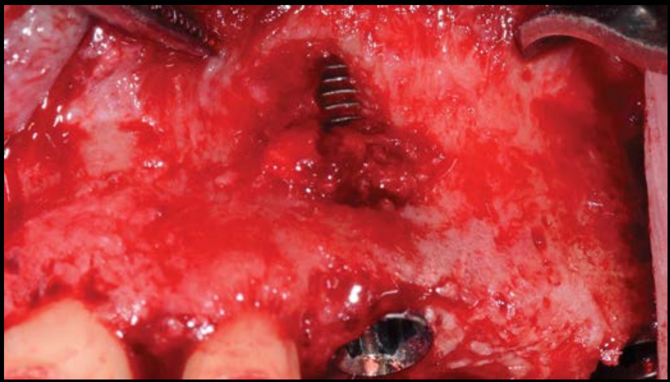


Figure 9: Apical fenestration defect after placement of an implant in a restorative-driven position.

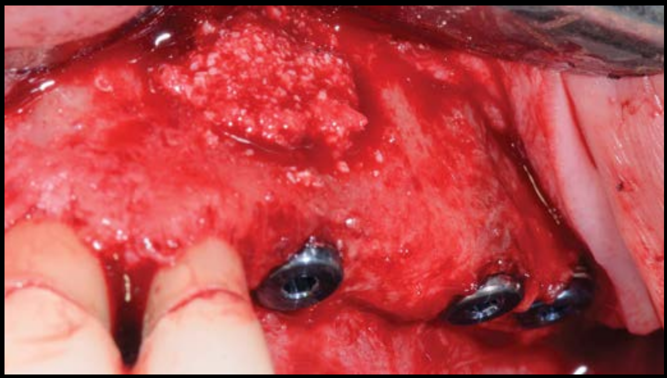


Figure 10: Use of autogenous bone chips and deproteinized bovine bone mineral particles to augment the fenestration defect.

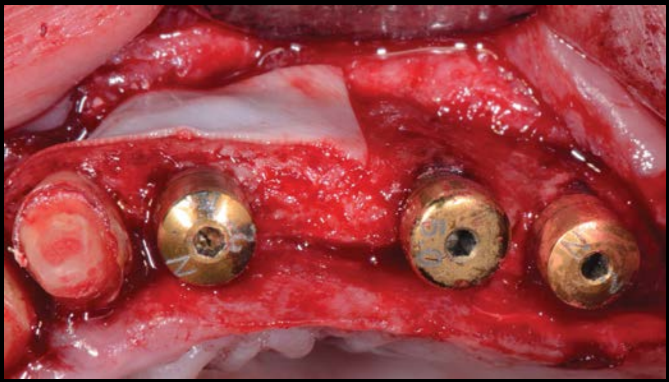


Figure 11: Use of collagen membrane to cover the augmented area.

Narrow impression transfers were used with an open-tray method, and stone cast models were fabricated. A diagnostic wax-up was used to create optimal tooth dimensions for the teeth to be restored. Provisional restorations (Anaxdent GmbH; Stuttgart, Germany) were fabricated in the laboratory **(Fig 13)**. The front four restorations were to be cemented on the patient's teeth by using a provisional cement (Telio CS Link, Ivoclar Vivadent; Schaan, Liechtenstein), and the distal six restorations were screw-retained on implants. Considerations for the selection of provisional materials were marginal adaptation, wear resistance and stability, color stability, ease of fabrication and maintenance, plaque retention, ease of polishing, durability, and retention. Provisional restorations permit the evaluation of function, phonetics, esthetics, tooth stabilization, occlusion, and tissue position. Our experience has shown that cervical contouring is the most predictable way to achieve esthetic integration of implants and restorations with soft tissues if there are delayed placement and restorations. On the model, the dental technician corrected the soft tissue and created a pontic, so we were able to copy the model and form the soft tissue in the mouth of the patient. Intraoral connection of the prosthetic component forces the surrounding tissues into the optimal configuration.

At the next appointment, we probed the bone so that we could manage the placement of the pontic. The most apical point of the pontic should be 2 to 3 mm away from the bone level **(Fig 14)**. Using a round bur, we performed some soft-tissue correction and placed the provisional restoration. The pontic position in relation to the gingiva is especially important and can be corrected by removing or adding flowable composite on the provisional restorations **(Figs 15 & 16)**.

Figure 12: Soft tissue 10 months after surgery.

Figure 13: Provisional restorations.

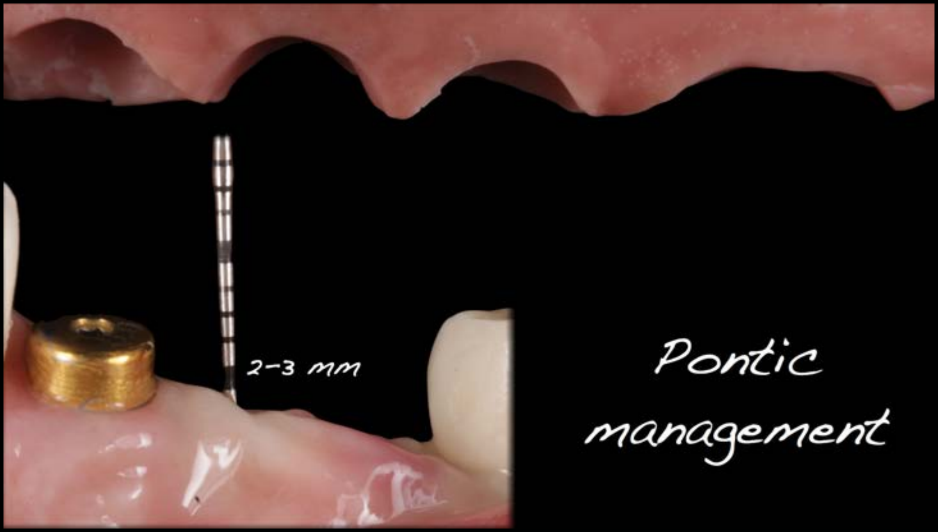


Figure 14: Pontic zone corrected with use of round bur and provisional restoration placed.

Final Restoration

After one month, when the patient approved the esthetic look and comfort, we moved on with a final impression **(Figs 17 & 18)**. To transfer all of the soft-tissue information, we used silicone (Express XT, 3M ESPE; St. Paul, MN) **(Figs 19-24)**. We placed the provisional restoration connected to the implant analogs in silicone, and then removed the provisional crowns to obtain a model of the soft tissue in the silicone. After that, we connected transfers and used flowable composite to fill the individualized volume in silicone.

All of the transfers were individually fixed in the mouth. The front four teeth were retracted with 00 non-impregnated cord to avoid problems with polymerization of the impression material.[14]

For the final impression, we used a custom tray so that there would be an even amount of material around; a-silicone was used as the impression material **(Fig 25)**.

For the canines and premolars, we constructed zirconium oxide abutments bonded onto a titanium base **(Fig 26)**. For the molars, we used full-anatomy lithium disilicate bonded onto a titanium base. Different methods were used for the abutments to compare soft tissue response and condition in the future. Lithium disilicate (IPS e.max, Ivoclar Vivadent)[15,16] was chosen as the final material because it exhibits biomimetic behavior indistinguishable from that of nature.[17] For the anterior crown structural design, our aim was to create a full-contour lingual part of lithium disilicate, limit the incisal edge, create interproximal cutback, and layer feldspathic ceramics. For the premolars and molars, we used full-anatomy lithium disilicate to increase strength without having to compromise the esthetic integrity of the crowns **(Figs 27-31)**.

Figure 15: Provisional restorations intraorally.

Figure 16: Occlusal view.

Figure 17: Modeling of soft tissue with provisional restorations.

Figure 18: Soft tissue after removal of provisional restoration shows the creation of volume.

Figure 19: All of the soft-tissue information was transferred, with the provisional restoration screwed into the implant laboratory analogs.

Figure 20: Provisional restoration screwed into implant laboratory analogs placed inside silicone.

Figure 21: Transfers connected to implant analogs, with flowable composite used to individualize transfers.

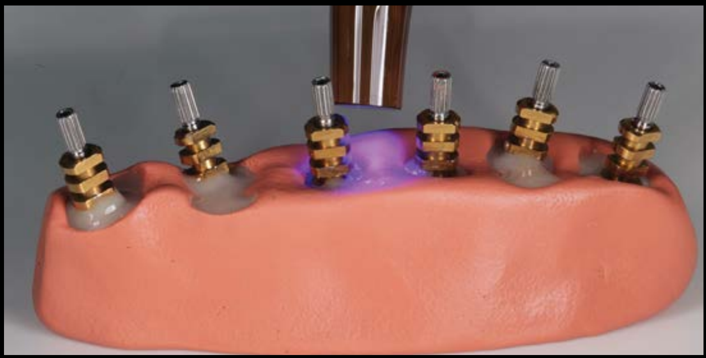


Figure 22: Light-cured for 30 seconds.

Figure 23: Transfers are individualized.

Figure 24: Ready to take impression with all transfers in the mouth.

Figure 25: Impression with a-silicone.

Figure 26: Final lithium disilicate restorations.

Figure 27: Zirconia abutments in place.

Figure 28: Isolation of neighboring teeth and retraction.

Figure 29: Intraoral view after treatment.

Figure 30: The patient's maximum smile. Although there is a slight difference of zeniths of the central incisors, the patient refused additional correction because during maximum smile it is not visible.

Figure 31: Portrait view, before and after treatment.

Discussion

In this case, the main goal was to switch from a removable construction to non-removable a permanent restoration to restore the patient's comfort, function, esthetics, and self-confidence. The first goal was to remove all of the structure that could cause inflammation and other problems. For surgery in this case, implants were placed according to Type IV implant placement in a fully healed ridge,[18] a benefit of which is mature soft tissue flap management. However, the typical limitation of Type IV implant placement in a fully healed ridge is insufficient bone volume. Despite the general tendency to develop vertical bone atrophy in distal maxillary regions as a result of both post-extraction ridge remodeling and maxillary sinus pneumatization,[19,20] this patient had sufficient bone height available. However, the bone width and alveolar ridge contours in the regions of the missing canines and premolars had some influence on our decision-making process.

In the current literature, there is still controversy regarding the adequate number, configuration, and distribution of implants in cases of multiple missing teeth. Nevertheless, investigators in prospective long-term clinical trials have confirmed the use of implant bridges supported by mesial and distal implants and a central pontic.[21,22] This finding led to our decision to place implants in the regions of the canines and second premolars and fabricate pontics to restore the first premolars where bone width and ridge configuration were compromised. Moreover, this method helps prevent the complications that sometimes occur with multiple adjacent implants in esthetic regions. Also, the dental technician can use the pontic contours to shape peri-implant soft tissues to achieve the optimum esthetic outcome.[23]

Figure 32: Final view. Now the patient can express emotions without any limitations.

In the region of the left canine, the ridge configuration in relation to the planned prosthetic axis presented two options: placing the implant in a compromised bone-driven position, or modifying the implant axis with the formation of an apical fenestration defect. Because there is ample evidence of success with the use of guided bone regeneration to reconstruct alveolar bone dehiscences and fenestrations around dental implants,[24-26] the second option was chosen to provide optimum restoration-driven implant placement.

For the final restorative material, we had a choice of PFM, feldspathic, zirconium oxide, or lithium disilicate restorations. Lithium disilicate gave us the ability to create an esthetic result without sacrificing strength with use of both full-anatomy and layered techniques.

Summary

There are a variety of techniques and materials today to treat almost any clinical case and improve patients' smiles. Dental implants make it possible to have non-removable teeth that can be integrated esthetically and functionally. Modern ceramic materials allow the recreation of tooth color, form, and structure to reestablish not only a patient's smile, but also their self-esteem **(Fig 32)**.

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The digital *jCD* version features a preview and link to an educational DentalXP video about this article.

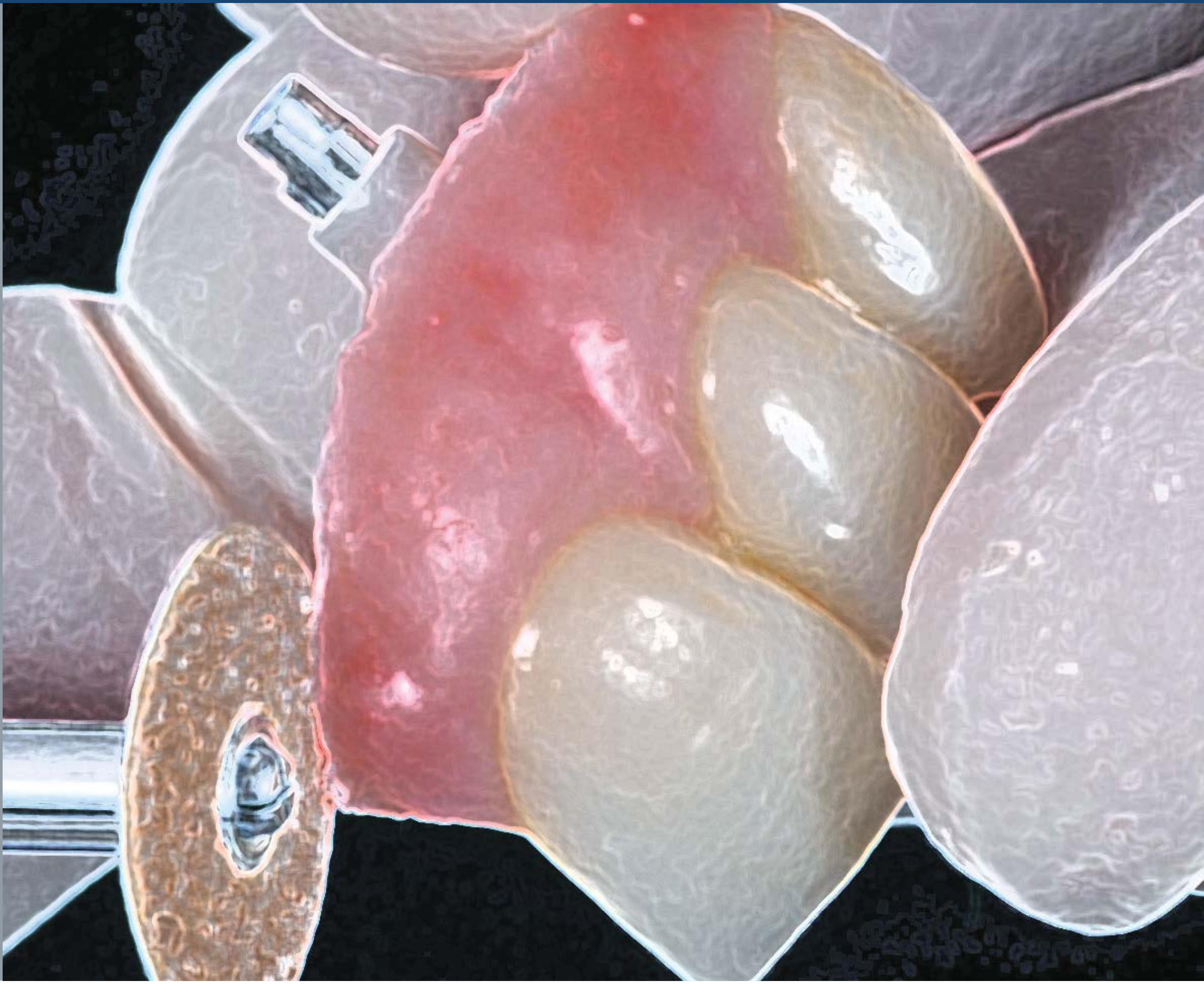
Editor's Note: This article is adapted from "*Digital Smile Design: A Tool for Treatment Planning and Communication in Esthetic Dentistry*" (QDT 2012, vol. 35, p. 103). Adapted with permission from Quintessence Publishing.

Abstract

Digital Smile Design is a multipurpose digital tool with clinically relevant advantages: It can strengthen esthetic diagnostic abilities, improve communication between team members, help organize treatment planning, create predictable systems throughout treatment phases, enhance patients' education and motivation, and increase the effectiveness of case presentation. This article describes the main steps of introducing this practical tool to the clinician's esthetic restorative practice.

Key Words: Digital Smile Design, esthetics, treatment planning, communication, presentation

> Excellence will never be achieved by chance; rather, it comes from a consistent, systematic approach to diagnosis, communication, treatment planning, and implementation.



Introduction

Excellence will never be achieved by chance; rather, it comes from a consistent, systematic approach to diagnosis, communication, treatment planning, and implementation. The incorporation of protocols and checklists[1-7] for quality control and information management help to guarantee that every critical point is performed effectively, is double-checked, and is communicated correctly.

To obtain predictable and consistent outcomes, the practitioner should define the design of the restorative treatment at an early stage. The data must guide the succeeding phases of the rehabilitation,[8] scientifically integrating all of the patient's needs and desires and the patient's functional, structural, and biological issues into the esthetic treatment design. The data serve as a frame of reference for the treatment that will be performed.[9,10] However, many of these pieces of information may not be taken into consideration if their real meaning is not transferred in an adequate way to the design of the restorations.

Digital Smile Design is a multipurpose digital tool with clinically relevant advantages. It can strengthen esthetic diagnostic abilities, improve communication among team members, create predictable systems throughout the treatment phases, enhance patients' education and motivation through visualization, and increase the effectiveness of case presentation. Because using DSD can make diagnosis more effective and treatment planning more consistent, the effort required to implement it is worthwhile and will make the treatment sequence more logical and straightforward, saving time and materials and reducing the cost of treatment.

Figure 1: Preoperative extraoral view 20 years before first appointment showing ankylosed teeth #21 and #22.

Figure 2: Preoperative extraoral view at first appointment.

Clinically Relevant Advantages

The advantages of using DSD are as follows:

- esthetic diagnosis
- treatment planning and communication
- feedback
- patient care
- case presentation
- education.

Esthetic Diagnosis

DSD allows a careful esthetic analysis of the patient's facial and dental features and a gradual discovery of many critical factors that might have been overlooked during the clinical, photographic, or study model evaluation. Drawing reference lines and shapes over extra- and intraoral digital photographs in presentation software (such as Keynote [Apple; Cupertino, CA]; PowerPoint [Microsoft; Redmond, WA]; DSD software; or Smile Designer Pro [Tasty Tech; Toronto, Ontario, CA]), following a predetermined sequence, helps widen the diagnostic vision. This visualization process also helps the team to assess and understand limitations and risk factors such as asymmetries, disharmonies, and esthetic principle violations, adding critical data to the process of treatment planning.[1] Choosing the appropriate technique is easier once problems have been identified and the solution clearly visualized. The main steps related to diagnosis are shown in **Figures 1-11**.

Figure 3: Profile issues: Skeletal Angle Class II.

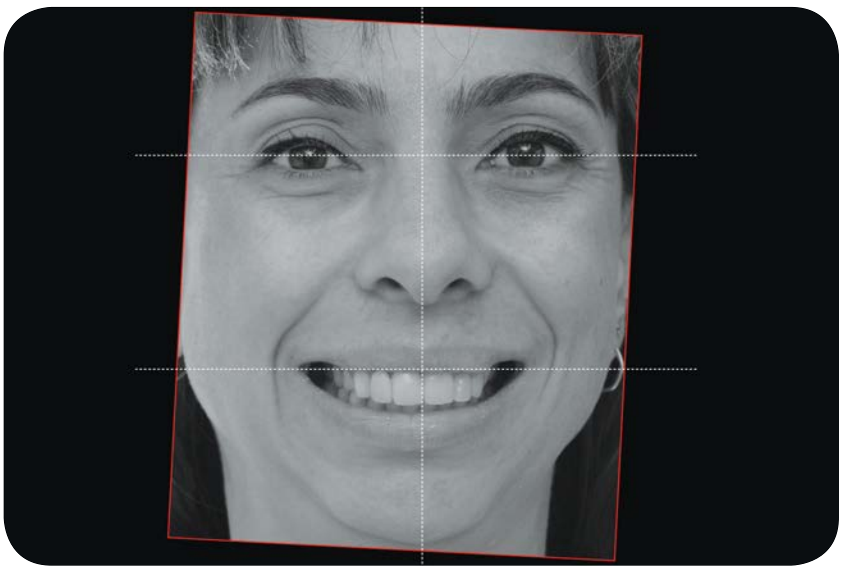


Figure 4: Digital facebow in DSD software.

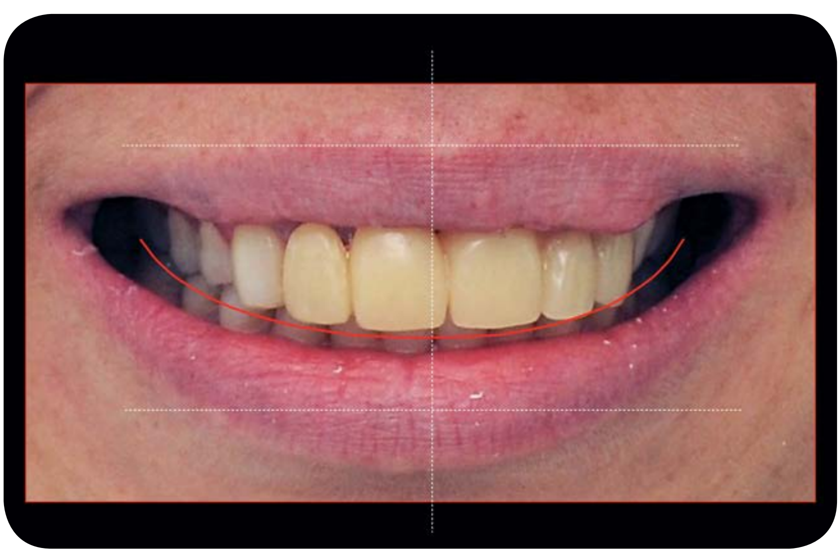


Figure 5: Facial lines overlapping the smile in DSD. The facial cross and digital wax rim (red curve) is visible.

Figure 6: Calibrating the intraoral photograph to the facial photograph.

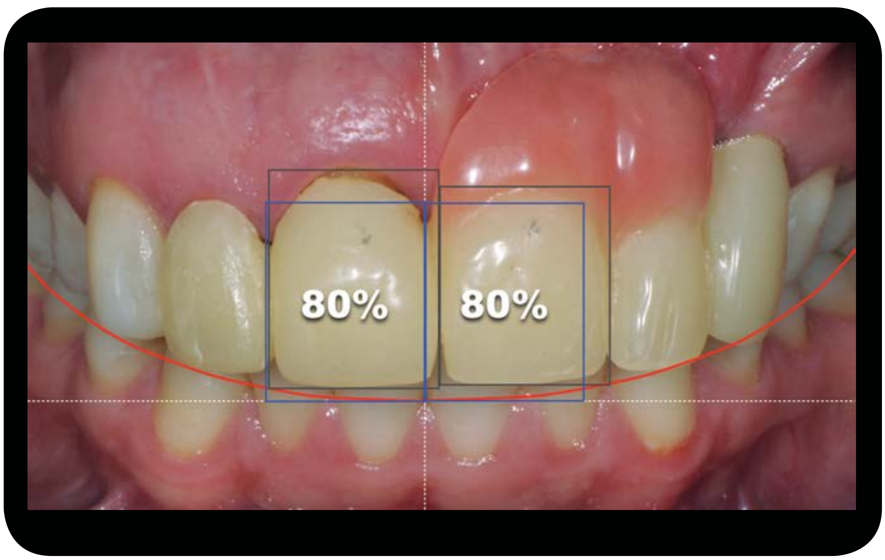


Figure 7: Central incisor tooth proportion analysis.

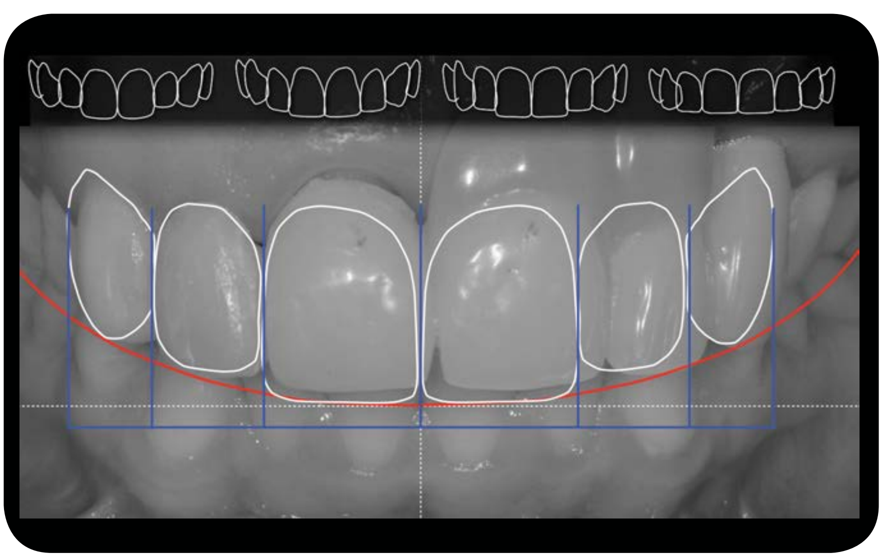


Figure 8: Interdental proportion guide and tooth outline according to morpho-psychology.

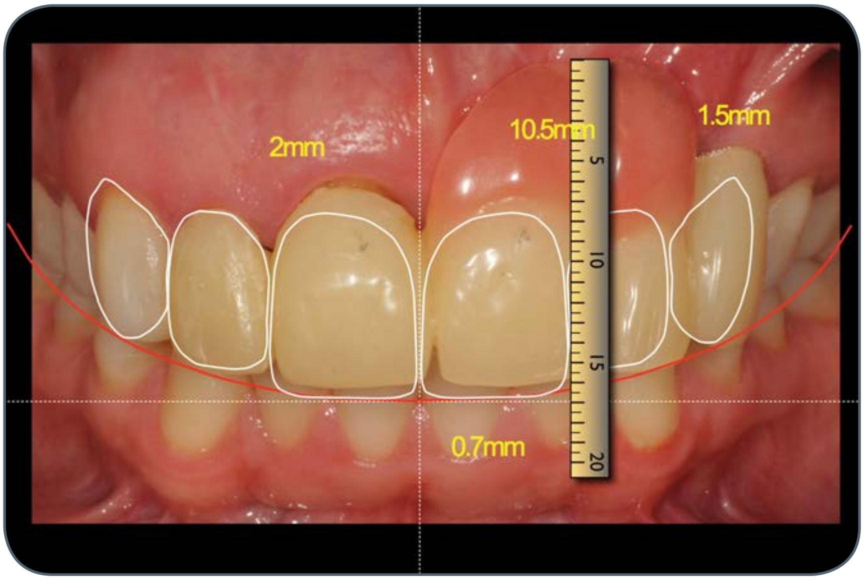


Figure 9: The digital ruler, measuring the gingival and incisal discrepancies for treatment planning and for guiding the wax-up.

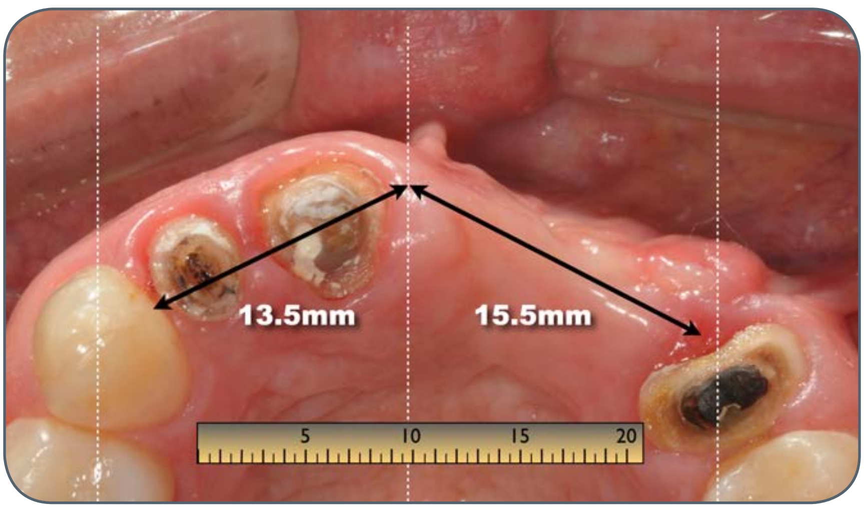


Figure 10: Occlusal analysis in DSD, detecting a mesiodistal space discrepancy anteriorly.

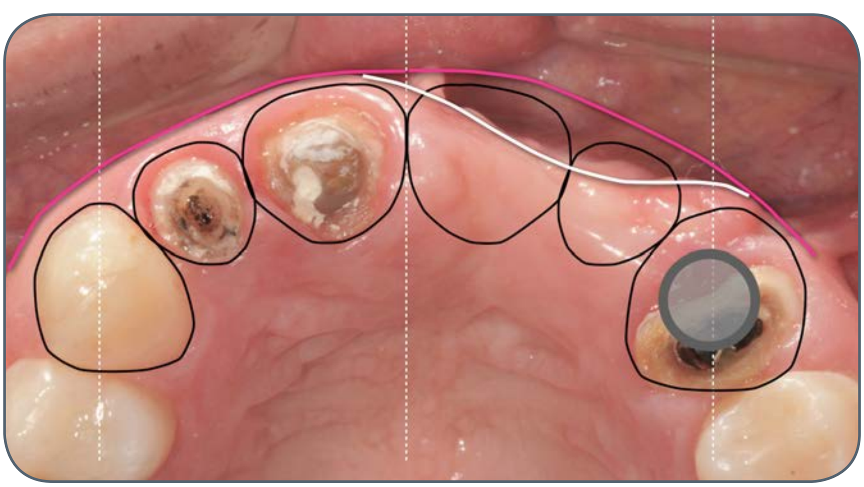


Figure 11: DSD drawings for better understanding the space management possibilities, implant position, and horizontal ridge reconstruction.

Treatment Planning and Communication

The main goal of the DSD protocol is to simplify communication, transferring key information from the patient's face to the working cast and then to the final restoration. The DSD protocol allows for effective communication between the interdisciplinary team members, including the dental technician. Team members can identify and highlight discrepancies in soft- or hard-tissue morphology and use high-quality images on a computer screen to discuss the best possible solutions for the case. Every team member can add information directly on the slides, either in writing or by using a voice-over function, thus simplifying the process even more. All team members can access this information whenever necessary by using shared files and changing or adding new elements during the diagnostic and treatment phases.

Traditionally, the dental technician has implemented the smile design with a restorative wax-up. The dental technician creates shapes and arrangements in accordance with restricted information, following instructions and guidelines provided by the dentist in writing or by phone. In many cases, the technician is not given enough information to use his or her skills to their maximum potential, and the opportunity to produce a restoration that will truly satisfy the patient is missed.

When the treatment coordinator or another member of the restorative team who has developed a personal relationship with the patient takes responsibility for the smile design, the results are likely to be superior. This team member has the ability to communicate the patient's personal preferences and morpho-psychological features to the laboratory technician, providing information that can elevate the quality of the restoration from one that the patient sees as merely adequate to one that the patient sees as exceptional.[7,8,11]

With this valuable information in hand and from the two-dimensional DSD, the dental technician can develop a three-dimensional wax-up more efficiently, focusing on developing anatomical features within the parameters provided, such as planes of reference, facial and dental midlines, recommended incisal edge position, lip dynamics, basic tooth arrangement, and the incisal plane. Transferring this information from the wax-up to the "test-drive" phase is achieved through a mock-up or a provisional restoration.[4,6,12] The design of the definitive esthetic restorations should be developed and tested as soon as possible, guiding the treatment sequence to a predetermined esthetic result.[13] Efficient treatment planning results in the entire treatment team being able to do a better job of identifying the challenges they will face and helps expedite the time to initiate and ultimately complete treatment.[8,14] The steps related to the treatment planning and the sequence performed are shown in **Figures 12-31**.

Feedback

DSD allows precise evaluation of the results obtained during every phase of treatment. The treatment sequence is organized on the slides with the photographs, videos, reports, graphics, and drawings, making this analysis simple and effective. Any team member can access the slide presentation at any time and check what was done until that moment. With the digital ruler, drawings and reference lines can be created so that it is possible to perform simple comparisons between the "before" and "after" images, determining whether they are in accordance with the original planning or whether any other adjunctive procedures are necessary to improve the outcome. The dental technician also gains feedback related to tooth shape, arrangement, and color so that final refinements can be made. This constant double-checking of information ensures that a higher-quality product will be delivered from the laboratory and also provides a great learning tool for the entire interdisciplinary team.

This process also becomes a useful library of treatment procedures that can be used in many different ways. Going back to old cases and understanding visually how they were treated is effective as a learning experience.

Patient Care

DSD can serve as a marketing tool to motivate patients so that they can better understand the issues and treatment options, compare "before" and "after" images, and understand all the work that was involved. Moreover, creating slides of treatments performed generates a personal library of clinical cases that can be shared with other patients and colleagues, and the most appropriate cases can be transformed further into interesting slide shows of one's work.

Case Presentation

DSD is designed to make treatment-planning presentation more effective and clear because it allows patients to see and better understand the combined multiple factors responsible for their dental and facial issues. Case presentation will be more effective and dynamic for these patients because the problems will be superimposed over their own photographs, increasing patient understanding, trust, and acceptance of the proposed plan. The clinician can express the severity of the case, introduce treatment strategies, discuss the prognosis, and make case management recommendations.[1] The case presentation also can be used for medico-legal purposes, registering the improvements that were achieved and the reasons for each decision made during the treatment.

Education

DSD aims to improve academic presentations by adding visual elements to the slides to make what the presenter says more clear in visual terms. This allows the audience to better understand and see what is being taught, because all of the information is presented in a clear, concise, and visual format.

Digital Smile Design Workflow

The DSD protocol was performed by the authors using Keynote or PowerPoint, but specially developed software such as Smile Designer Pro or DSD software is highly recommended. This type of software allows simple manipulation of digital images, as well as the addition of lines, shapes, drawings, and measurements over the clinical and laboratory images. In this article, the main steps for using DSD are described and illustrated by showing the resolution of a complex case **(Figs 12-31)**. It is important to emphasize that DSD was used from treatment inception and helped the patient to visualize all her clinical issues, understand potential solutions, and choose the option that best fit her needs and wishes.

> "Choosing the appropriate technique is easier once problems have been identified and the solution clearly visualized."

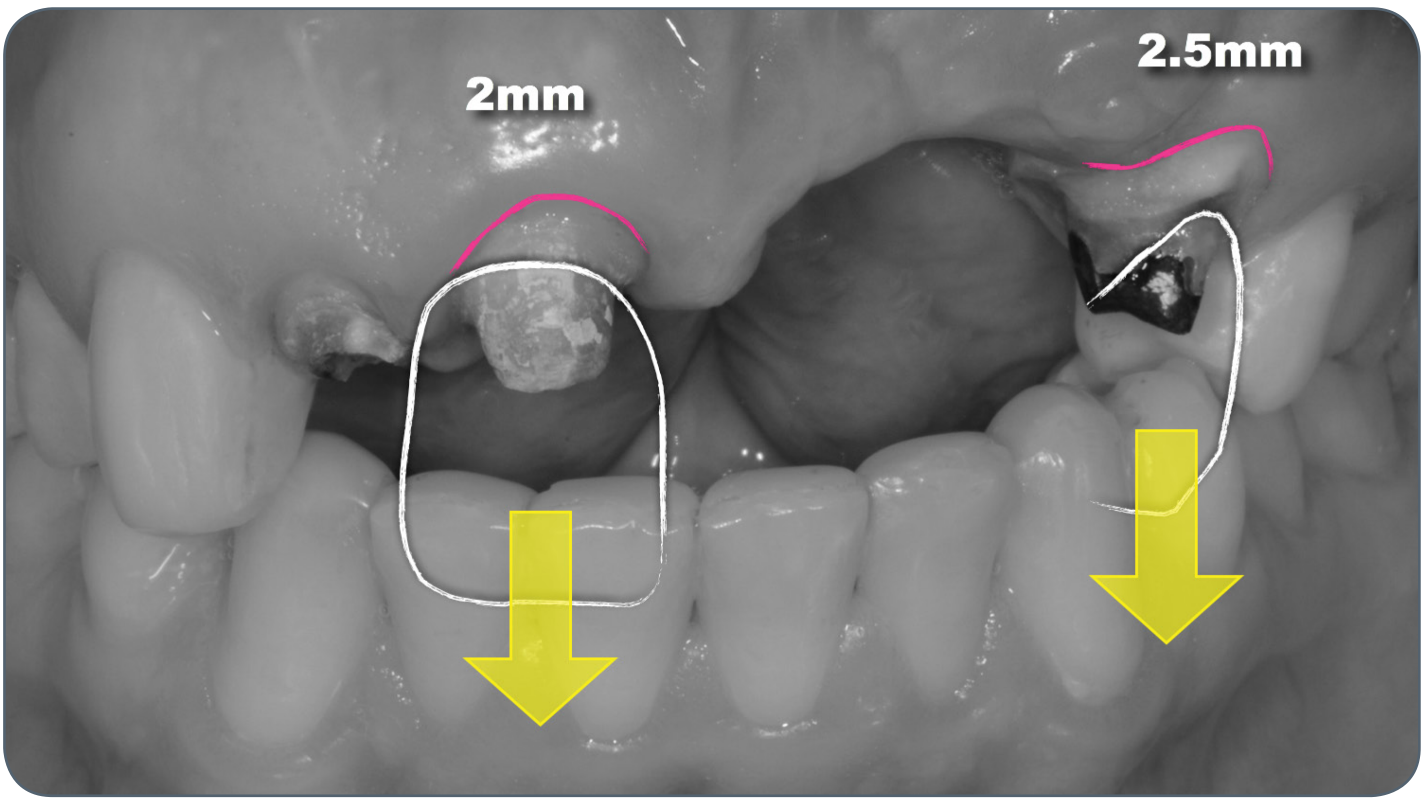


Figure 12: The plan: Orthodontic extrusion of #11 for bone and soft-tissue repositioning according to the DSD analysis. Tooth #23 would be extracted because of lack of bone support and esthetic limitations.

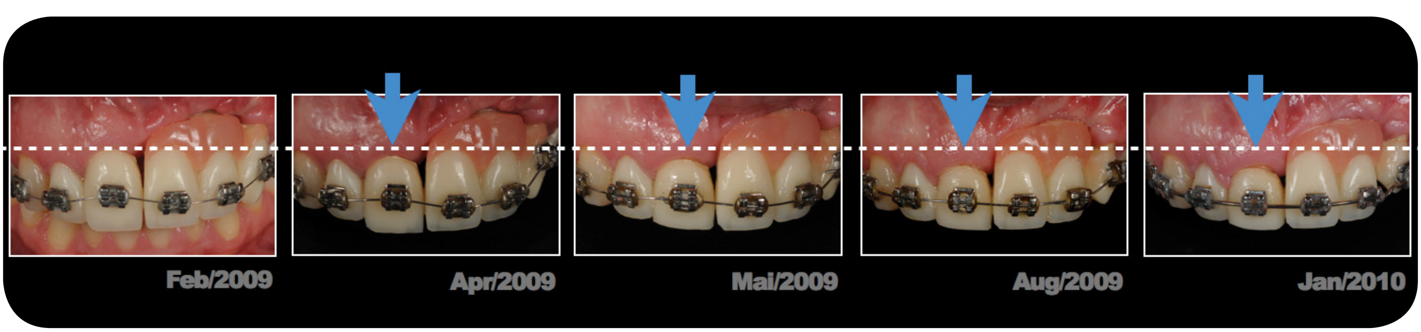


Figure 13: Orthodontic extrusion of #11.

Figure 14: The bridge design after extracting the structurally compromised canine. There was an esthetic improvement because of the artificial gingiva extension over #23, leveling the pink esthetics and placing the interface between natural and artificial gingiva in a less esthetically demanding area, distally behind the canine.

Figure 15: Final position for lithium disilicate restorations over natural abutments.

Figure 16: Try in and analysis of white esthetic integration with the face.

Figure 17: The patient returned one week after seating for the improvement of the artificial pink interface. The tissue was ideally healed and adapted to the new emergence profile, so there was an ideal environment in which to bond the pink composite to the pink ceramics intraorally.

Figure 18: The bridge was unscrewed and prepared for bonding. The first step was to roughen the surface for better retention.

Figure 19: Acid etching.

Figure 20: Applying the silane.

Figure 21: Applying the bonding agent.

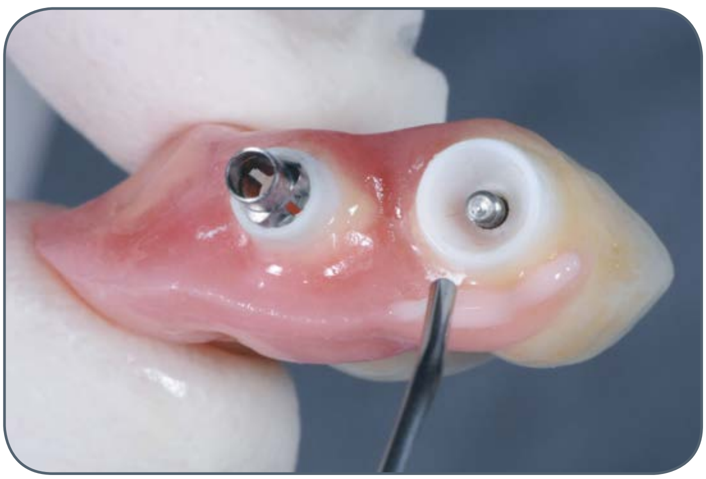


Figure 22: Applying the first layer of flowable pink composite chairside to guarantee better bonding without interference of the saliva.

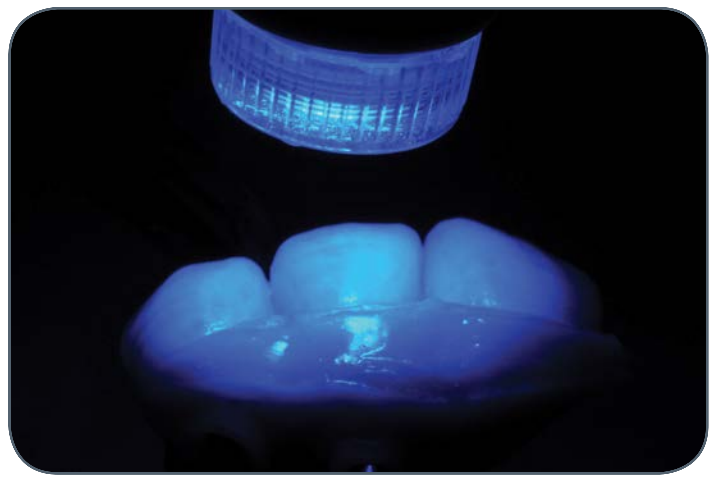


Figure 23: Light-curing before inserting the bridge in the mouth to proceed with the direct composite buildup.

Figures 24 & 25: Intraoral pink composite buildup produced by using a micro brush and thin-tip stain brushes. Different colors and pigments were used to better match the natural gingiva.

> "The design of the definitive esthetic restorations should be developed and tested as soon as possible, guiding the treatment sequence to a predetermined esthetic result."

Figures 26a-26c: Finishing and polishing the restoration outside the mouth.

Figure 27: Final seating after testing hygiene procedures; floss should be able to go all the way around and underneath the artificial gingiva.

Figures 28a-28c: Final outcome.

Figure 29: The positive emotional response of the patient reflects a successful treatment.

Figure 30: Genioplasty was performed to improve the profile; a significant difference achieved with a relatively simple procedure. The ideal facial integration was achieved with an interdisciplinary approach.

Figure 31: Postoperative extraoral view after two years.

Summary

DSD is a practical multi-use tool with clinically relevant advantages. It can strengthen esthetic diagnostic abilities, improve communication among team members, create predictable systems throughout the treatment phases, enhance patients' education and motivation, and increase the effectiveness of case presentation. The drawing of reference lines and shapes over the patient's photograph, following a predetermined sequence, allows the team to better evaluate the esthetic relation among the teeth, the gingiva, the smile, and the face.

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> "The drawing of reference lines and shapes over the patient's photograph, following a predetermined sequence, allows the team to better evaluate the esthetic relation among the teeth, the gingiva, the smile, and the face."

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Disclosure: Dr. Calamita did not report any disclosures.

Dr. Coachman is the owner of Well Clinic Esthetic Dentistry, Digital Smile Design Center in São Paulo.

Disclosure: Dr. Coachman is the developer of Digital Smile Design.

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Two Immediate Temporization Methods Exemplified:

Flap vs. Punch Technique in Implant Surgery

Provisional Restoration of Single Tooth Implants into Healed Ridges in the Esthetic Zone

The digital *jCD* version features a preview and link to an educational DentalXP video about this article.

Stephen J. Chu, DMD, MSD, CDT
Dennis P. Tarnow, DDS

CE CREDIT

After reading this article, the participant should be able to:

1. Understand some of the advantages of utilizing immediate non-occlusal loading of implants with temporary crowns when placed in healed ridges.

2. Recognize the differences in temporary crown fabrication techniques when implants are placed using a flap or flapless technique.

3. Understand the importance of subgingival emergence profiles of temporary crowns when a flap or flapless implant protocol is used.

Abstract

Protocols and techniques for immediate tooth replacement in the esthetic zone have become more popular and predictable within the past decade. Two different clinical scenarios are presented where immediate temporization of implants placed into healed or augmented ridges is exemplified. The benefits of augmentation prior to implant placement and temporization are that flap elevation is not required; therefore, the blood supply to the labial plate is not compromised, thereby eliminating potential midfacial recession. In addition, the soft tissue subgingival shape of the temporary crown can be non-surgically sculpted at the time of implant placement since the patient is already anesthetized.

Key Words: delayed implant placement, immediate temporization, transmucosal "punch" technique, flat subgingival contours, blood supply

Introduction

Many factors should be considered when placing implants into the esthetic zone, in order to determine which procedure is best to achieve the desired outcome. Current technologies, knowledge, and techniques may not only allow condensed healing time of implants to final delivery of the definitive restoration, but also a simultaneous immediate temporary crown. This can be of tremendous benefit to both patients and clinicians since chairside procedures can be condensed into fewer appointments, thereby decreasing overall treatment time without potential risk of implant failure.

Immediate post-extraction socket implants in the esthetic zone have gained popularity and success in regard to survival, osseointegration, and esthetic outcomes over the past decade,[1-11] although this type of treatment requires a specific skill set of knowledge within the dental team to achieve a predictable outcome, especially in regard to optimal esthetics. Also, the philosophy of immediate treatment is quite diverse from delayed implant placement: one of "preservation" of existing hard and soft tissues versus "creation" of lost structures.

Delayed implants are frequently necessary since an intact or Type I socket[12] is not always present after tooth removal due to the prior damage to the periodontium from the diseased tooth. In these situations, it is often necessary to reconstruct the ridge at the time of tooth removal or after ridge healing. Salama and colleagues have stated that it is best to do all site development prior to implant placement to ensure a predictable result.[13] In addition, patients undergoing time-consuming procedures such as orthodontic therapy to create the proper space adjacent to an edentulous site, treatment planned to receive an implant, are frequently anxious to receive a fixed temporary crown restoration in lieu of an existing denture tooth fastened to an orthodontic arch wire.

In 2011, den Hartog and colleagues reported survival rates of immediate non-occlusally loaded single implants in the esthetic zone. The results showed a 3% difference in survival rate, 97% versus 100%, respectively, if an immediate temporary restoration was placed rather than burying the implant as a two-stage implant procedure.[14]

However, questions still remain in regard to immediate temporization of implants placed into healed or augmented edentulous sites:

- What techniques and clinical procedures are best to offer a predictable result?
- When can implant placement be combined with site augmentation and simultaneous temporization?

> "Delayed implants are frequently necessary since an intact or Type I socket is not always present after tooth removal due to the prior damage to the periodontium from the diseased tooth."

- What will the esthetic outcome be?

Two case reports are presented here to address these questions as well as to exemplify immediate tooth replacement with a temporary screw-retained crown. The first addresses hard tissue augmentation combined with implant placement; the second presents techniques that can be used when augmentation has been performed prior and separate to implant placement and temporization.

Case Report 1

A 24-year-old female presented with a missing tooth #7. This tooth had a prior history of root canal therapy with a subsequent fracture of the coronal tooth structure **(Fig 1)**. The tooth was deemed non-restorable and was subsequently extracted and a transitional removable partial prosthesis (RPP) delivered. After six months of healing of the edentulous site, an implant was treatment planned to replace #7 **(Fig 2)**. Since the existing interproximal papillae were intact, a papilla-sparing incision design was employed.[15] The clinical surgical challenge would be to increase the facial-palatal dimension of the edentulous site because collapse had occurred after tooth removal **(Fig 3)**. A 3.25-mm diameter implant (Certain, Biomet 3i; Palm Beach, FL) was placed securely in bone with a minimum torque value of 35 to 40 Ncm to allow immediate temporization of the implant **(Fig 4)**. Implant placement toward the palatal aspect of the ridge was critical to allow fabrication of a screw-retained temporary crown, thereby eliminating the risk of cement retention and flap irritation.[16] A provisional screw-retained implant cylinder (PreFormance Temporary Cylinder, Biomet 3i) was placed and an acrylic tooth was relined onto the post part of the abutment **(Figs 5 & 6)**. Autopolymerizing acrylic resin (Super-T, American Conglomerated; Solon, OH) was added to the temporary crown to fill in the deficient areas; flat subgingival contours were created to allow proper flap adaptation **(Fig 7)**.[17] A bone allograft (Puros, Zimmer Dental; Carlsbad, CA) and resorbable membrane (BioMendExtend, Zimmer Dental) were placed to increase the width of the facial ridge and the flap was sutured around the temporary crown restoration **(Figs 8-10)**. Normal healing of the surgical area was noted two weeks post-treatment **(Fig 11)**. The implant and bone graft were allowed to heal for five months before impression-making and final restoration. The ridge width was increased to allow predictable restoration of the edentulous site as well as esthetic integration of the porcelain-fused-to-metal restoration **(Figs 12-14)**.

Figure 1: Preoperative radiograph of root canal-treated tooth #7, which eventually fractured.

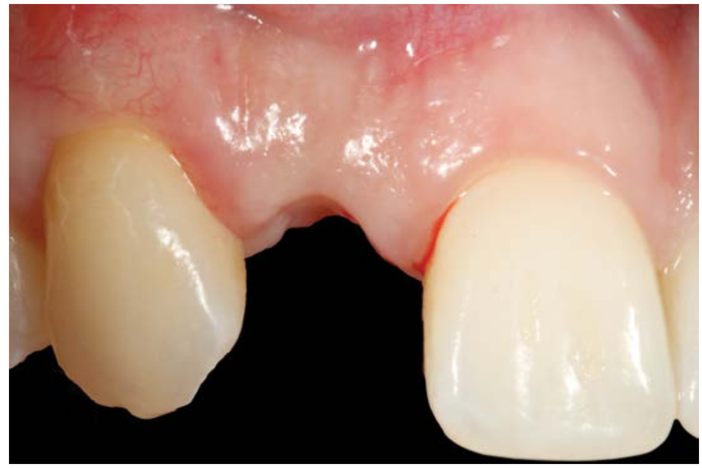

Figure 2: After six months' post-extraction healing of the ridge, an implant was treatment planned for placement.

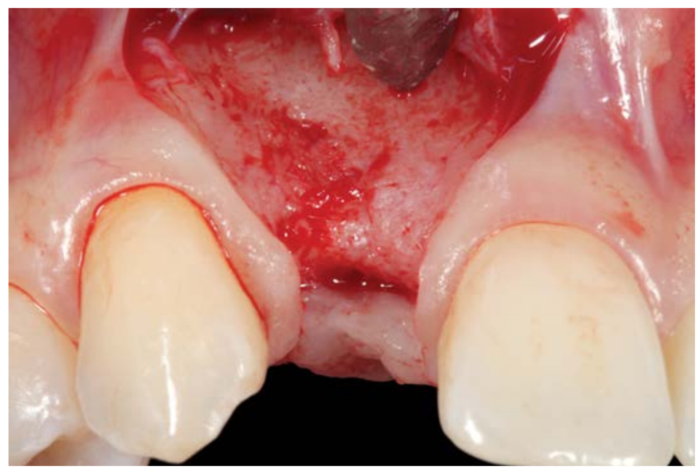

Figure 3: A papilla-sparing incision design was used with full flap elevation to expose the labial bone plate.

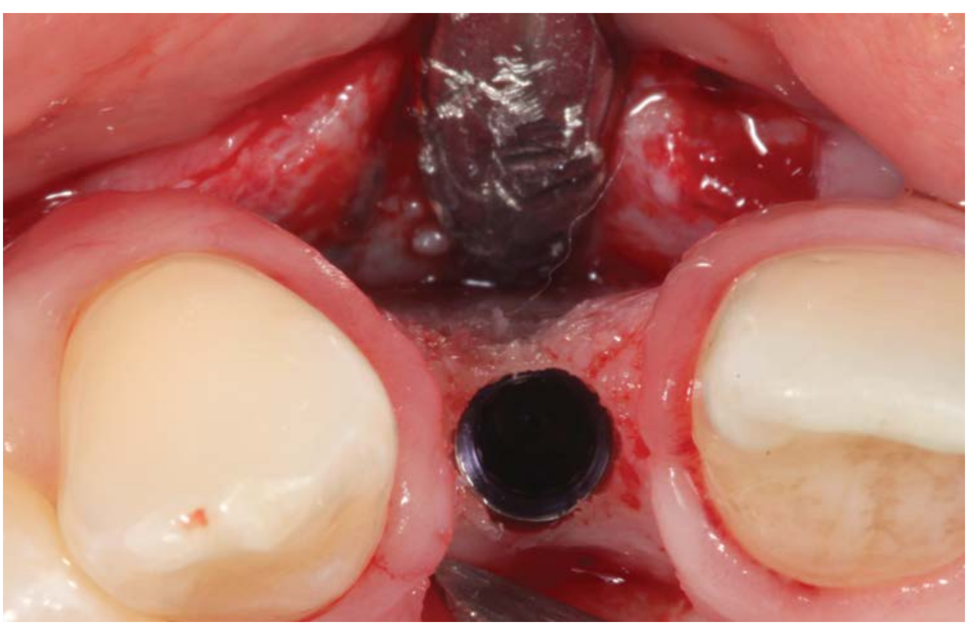

Figure 4: The narrow width of the edentulous ridge was visualized and a 3.25-mm diameter implant was placed completely within the bony housing.

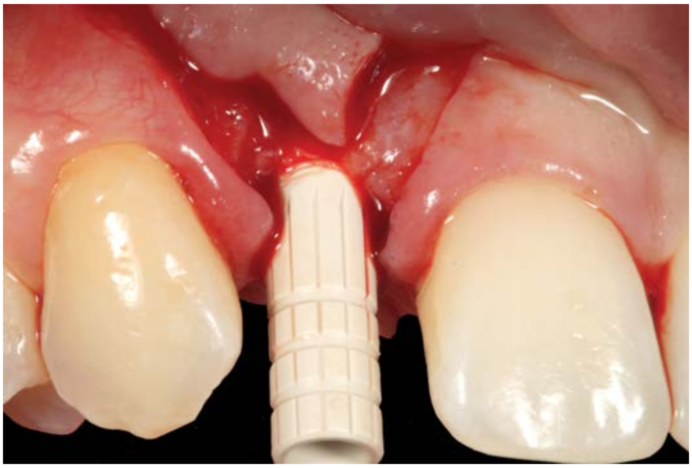

Figure 5: The construction of the temporary crown was made prior to grafting of the collapsed ridge. A screw-retained straight temporary cylinder was seated.

Figure 6: An acrylic crown facing was relined with autopolymerizing acrylic onto the implant temporary cylinder.

Figure 7: The final temporary crown was constructed using the Nealon liquid-powder technique. Flat subgingival crown contours were created to allow proper flap adaptation with primary closure.

Figure 8: A bone allograft was placed to augment the collapsed labial aspect of the edentulous ridge in combination with implant placement and temporization.

Figure 9: A resorbable membrane was placed over the bone allograft material for guided regeneration.

Figure 10: Proper subgingival contouring of the provisional restoration allowed primary flap closure. The temporary crown was relieved in maximum intercuspal position and lateral excursions.

Figure 11: Two weeks' postoperative healing of #7.

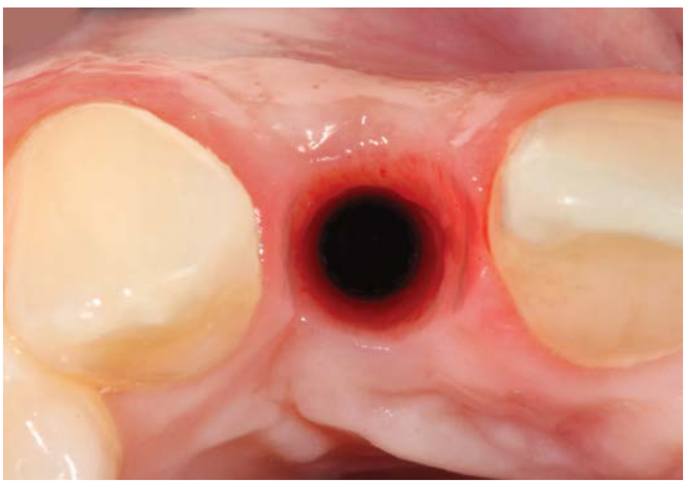

Figure 12: The temporary crown was disconnected after five months' post-healing. Note the fullness of the labial ridge after augmentation.

Figure 13: The definitive screw-retained porcelain-fused-to-gold crown inserted. Esthetic and functional integration was achieved.

Figure 14: Post-treatment radiograph of implant #7.

Case Report 2

This case report exemplifies a difference between the prior clinical example where the ridge was reconstructed simultaneously with the placement of an implant and temporary restoration. In this clinical scenario, the ridge was developed prior to implant placement and temporization.

A 45-year-old female patient presented with a retained upper right primary canine tooth (UR-c) with a horizontally impacted permanent cuspid **(Figs 15-17)**. The primary and permanent canine teeth were extracted, the site was reconstructed with bone allograft material (Puros), and a transitional "flipper" RPP fabricated. After six months' healing, the ridge was completely healed and reconstituted in terms of size, shape, and bone volume **(Figs 18-20)**. A transmucosal "punch" technique was used to remove the soft tissue to the crest of bone, thereby allowing the implant to be placed employing a "flapless" technique **(Figs 21-26)**. The trade-off in this technique is that implant placement surgery is more demanding since it is essentially performed "blind" through a 5-mm diameter opening **(Fig 24)**. Again, a straight screw-retained temporary abutment was placed onto the implant **(Fig 27)** and an acrylic tooth was relined onto the surface. Using the Nealon technique[18] (i.e., liquid-powder paintbrush technique), acrylic was added to the undercontoured areas of the temporary crown to create the proper final contour **(Fig 28)**. The benefit of this flapless or punch surgical technique allows the soft tissues to be molded and stretched[19] at the time of implant placement since there are no vertical releasing incisions to negotiate flap adaptation and suturing. And most importantly, the blood supply to the labial aspect of the edentulous ridge is neither compromised nor interrupted since flap elevation is absent with this technique. The periosteum is the only other source of blood supply to the labial plate besides the endosteum (marrow); therefore, with full flap elevation this source is no longer present. The occlusion on the temporary crown was relieved in both maximum intercuspal position (MIP) and lateral excursive movements **(Fig 29)**. After a minimum healing time of three to four months, the temporary crown was disconnected **(Fig 30)** and an implant-level impression was made using autopolymerizing resin [Pattern Resin LS, GC America; Alsip, IL) to register the shape of the soft tissue profile **(Fig 31)**. A definitive screw-retained porcelain-fused-to-gold alloy crown was fabricated **(Fig 32)** and inserted **(Fig 33)**. The integration of form, function, and esthetics was achieved predictably with this technique of ridge reconstruction prior to implant placement with an immediate non-occlusally loaded temporary crown.

Figure 15: Clinical preoperative condition of retained primary tooth UR-c.

Figure 16: Periapical radiograph of preoperative condition of retained primary tooth UR-c with horizontal impaction of permanent #6.

Figure 17: CBCT radiograph of preoperative condition of retained primary tooth UR-c with horizontal impaction of permanent tooth #6.

Figure 18: Labial view of healed edentulous ridge #6 after extraction of primary tooth UR-c and impacted permanent #6.

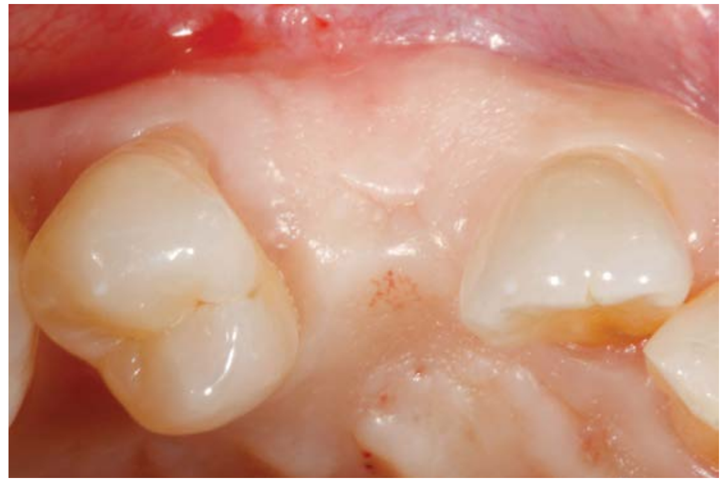

Figure 19: Occlusal view of the reconstructed edentulous ridge #6 with ample labial-palatal width and volume of the hard and soft tissues.

Figure 20: Six months' post-healing periapical radiograph of #6 showing proper radiopacity for implant placement.

Figure 21: A 5-mm diameter transmucosal soft tissue punch was used to create a circumferential incision of the supracrestal soft tissue over the edentulous ridge site.

> "The integration of form, function, and esthetics was achieved predictably with this technique of ridge reconstruction prior to implant placement with an immediate non-occlusally loaded temporary crown."

Figure 22: The soft tissue is excised over the osseous ridge crest using a sharp excavator.

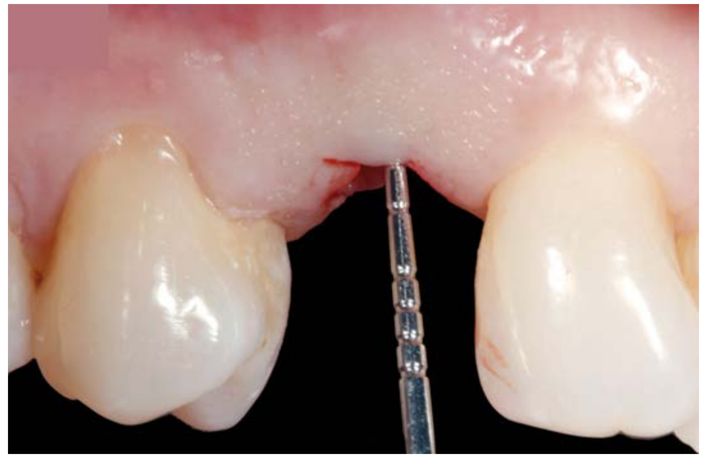

Figure 23: A periodontal probe was used to measure the amount of soft tissue thickness (4 mm) over the edentulous ridge bone crest.

Figure 24: A clean soft tissue incision was created with the punch and the access hole was slightly to the palatal aspect for “blind” implant placement.

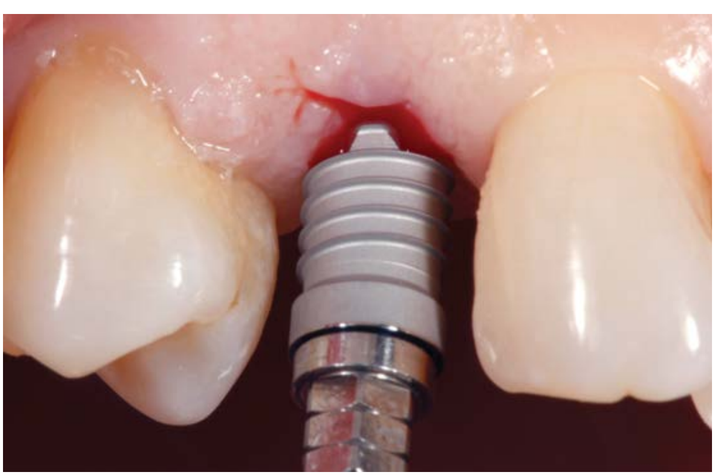

Figure 25: The implant was placed through the punch.

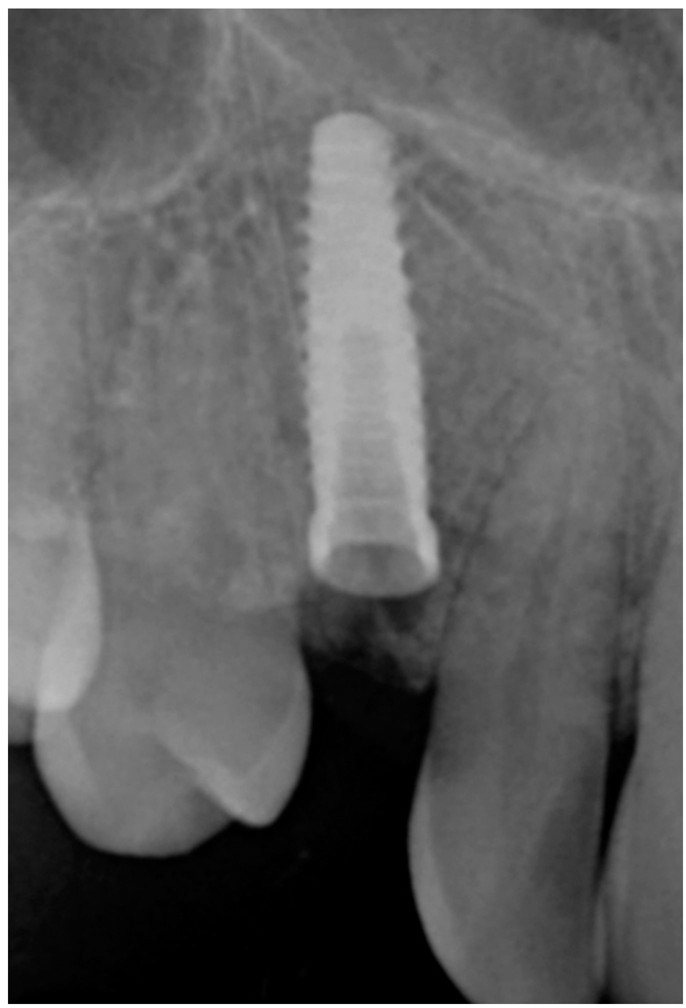

Figure 26: The seating of the implant was verified with a periapical radiograph.

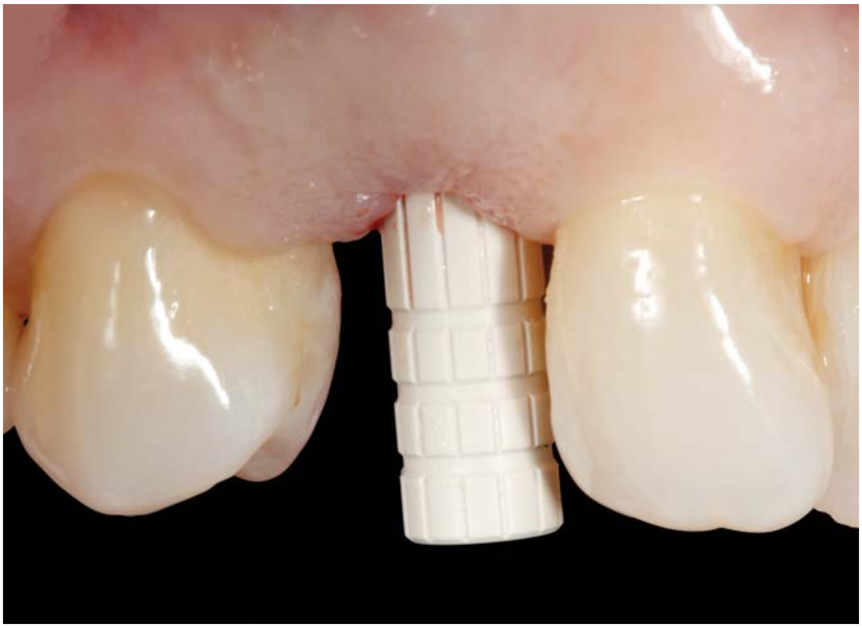

Figure 27: The screw-retained straight temporary cylinder was seated onto the implant to receive the temporary crown.

Figure 28: The liquid-powder paint on acrylic technique was used to add the proper final subgingival contour to the provisional implant crown. This would obviate the need to go back later and contour the tissue after implant healing.

Figure 29: The temporary crown was relieved in MIP and lateral excursive movements so it would be non-occlusally loaded.

Figure 30: After four months' post-surgical healing the provisional crown was disconnected. Notice the proper shape and profile of the peri-implant soft tissues, which were developed at the time of implant placement.

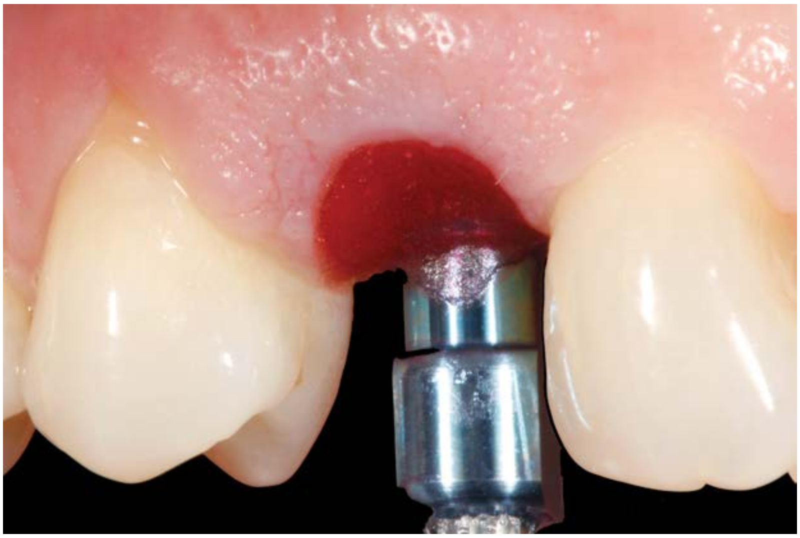

Figure 31: An implant-level impression transfer coping was placed onto the implant and pattern resin was used to register the soft tissue profile.

Figure 32: A definitive screw-retained porcelain-fused-to-gold crown was made for #6.

Figure 33: Esthetic and functional harmony of the implant restoration was achieved using the immediate temporization and transmucosal "punch" technique.

Summary

Immediate temporization can be performed with implants placed into post-extraction sockets (more commonly referred to as "immediate implants").

Implants can also be placed into healed ridges and an immediate temporary can be made on these implants even though the traditional healing time for bone maturation has not occurred.

With the new macro thread designs of current implants, this can be accomplished, the clinical keys being that the insertion torque value of the implant is high (40+ Ncm) and the temporary is not in occlusion.

When managing esthetic challenges on anterior implants, many factors must be considered prior to treatment. One of the primary challenges facing restorative dentists and surgeons alike is when an immediate temporary crown can be placed onto an implant that has been placed into a post-extraction socket. Equally as relevant is one that has been placed into a healed edentulous site. Using prior experience and evidence-based studies, the authors have reviewed and offered two methods for treating this clinical situation. The transmucosal "punch" technique requires prior ridge augmentation/reconstruction and greater surgical skill in implant placement. However, this technique offers greater control in temporary restoration fabrication in terms of crown contour and potentially less recession of the midfacial tissues since a labial flap is neither elevated nor required. By employing these methods, patient issues can be resolved in shorter and more predictable treatment times with lasting biologic and esthetic results.

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> “By employing these methods, patient issues can be resolved in shorter and more predictable treatment times with lasting biologic and esthetic results.”

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Implant Restorations (Prosthodontics/Fixed) AGD: Subject Code: 616

The 10 multiple-choice questions for this Continuing Education (CE) self-instruction exam are based on the article, *"Two Immediate Temporization Methods Exemplified: Flap vs. Punch Technique in Implant Surgery,"* by Stephen Chu, DMD, MSD, CDT; and Dennis Tarnow, DDS. This article appears on pages 118-129.

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1. To reconstruct the ridge for optimal implant placement, it is best to do which of the following?

a. Place an implant at the time of tooth extraction.
b. Reconstruct the ridge at the time of implant placement.
c. Do all site development prior to implant placement.
d. Place a bone graft at the time of implant placement.

2. Comparing the success rate between placing an immediate temporary implant restoration or burying the implant as a two-stage implant procedure, the study by den Hartog and colleagues showed that

a. there is a minimal (3 to 5%) difference in the success rate between the two procedures.
b. there is approximately a 25% improvement in the success rate when using a two-stage implant procedure.
c. there is approximately a 25% improvement in the success rate when an immediate temporary is used.
d. there is a minimal (3 to 5%) improvement when an immediate temporary is used.

3. Which of the following is a benefit of using a screw-retained temporary crown?

a. The implant can be placed more buccally in the extraction site.
b. The implant can be placed more palatally in the extraction site.
c. The risk of a screw loosening on the temporary crown is eliminated.
d. The risk of cement retention below the flap is eliminated.

4. Which of the following is a disadvantage of using a "flapless" technique during implant placement surgery?

a. There is more bleeding, therefore the surgical site is harder to see.
b. The surgery is more demanding due to the limited view of the surgical site without a flap.
c. An immediate temporary cannot be used with this technique.
d. An immediate temporary must be used with this technique.

5. What is the main advantage, from the surgical perspective, of using a flapless technique during implant placement surgery?

a. The surgery is easier and faster.
b. The soft tissues can be molded and stretched.
c. The surgery is less painful for the patient.
d. The blood supply to the edentulous ridge is not compromised.

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The all-new 2nd edition of the AACD Guide to Accreditation Criteria, *Contemporary Concepts in Smile Design: Diagnosis and Treatment Evaluation in Comprehensive Cosmetic Dentistry*, presents universally accepted smile design parameters established over several decades. A "must have" in your professional library, the following is an excerpt from Chapter One, Global Esthetics.

Figure 1: Smile line in harmony with the incisal plane.

An assessment of dental esthetics begins, quite simply, with the smile. If the images we are so intently evaluating are of beautiful and healthy teeth, then the frame that encircles these players on the stage are the soft tissues of the supporting structures, the lips, and their orientation in the face. Global esthetics focuses on these criteria that are observed in unretracted smiles: how the smile orients to the face. Understanding the parameters of this global matrix is a critical starting point for a smile that harmonizes with the patient, both physically and psychologically. These positions and contours of teeth do not occur "by accident"; rather, they are affected by the unique functional parameters of each patient. Violation of these criteria results in an unbalanced appearance that will affect the patient's esthetics and functional comfort. Criteria that constitute the global esthetic parameters are the smile line, the midline, the incisal edge position, the incisal plane, and the buccal corridor.

Smile Line

The **smile line (Fig 1)** refers to an imaginary line that is traced along the incisal edges of the maxillary anterior teeth and should mimic the curvature of the superior border of the lower lip while smiling. Consideration should be given to any significant lip asymmetry or extreme curvature of the lower lip.[1] A second criterion for the **smile line** illustrates that the centrals are preferably slightly longer (or at the very least not any shorter) than the cuspids along the incisal plane. The importance of this criterion can be observed when the centrals appear shorter than the cuspids along the incisal plane. This is referred to as a **reverse smile line**.[2]

The **lip line**, not to be confused with the smile line, refers to the position of the inferior border of the upper lip and thereby determines the display of either tooth or gingiva at this hard and soft tissue interface. The **gingival zenith** is defined by the most apical extent of the scallop of gingival-free margin of any particular tooth. Under ideal conditions the gingival zenith and the lip line should be congruent. The lip line while smiling is generally considered acceptable if it is within a range of 2 mm apical or coronal to the height of the gingival zenith of the maxillary centrals. The display of 3 to 4 mm (or more) of gingivae may introduce the consideration for alteration of the architecture to achieve an ideal result. An evaluation of the relative proportions of the teeth will help to suggest which alterations will be most appropriate. A lip line is considered low if there is absolutely no gingival tissue visible during smile formation. Conversely, a lip line is considered **high** if excessive gingival tissue is readily displayed while smiling. A high lip line presents an unforgiving reveal of all the aspects of the periodontal architecture and raises the esthetic risk assessment when considering treatment.[3]

The **smile line** together with esthetics, phonetics, and function helps determine the incisal edge position and influences length of the maxillary centrals. The following considerations may also serve as a guide to the clinician when assessing and designing the size, position, and shape of the maxillary central incisors.

1. Convention accepts as "pleasing," a range of 10 to 12 mm for the length of the maxillary centrals.[4]
2. The centrals are most likely too long if they cause lower lip impingement, dimpling, or entrapment during the formation of the "F" sound. This phonet-

ic test should be enunciated softly, not forcefully, as the muscles of the face can mistakenly accommodate in deliberate movement. In most cases, this exercise will not show if the teeth are too short. Ideal tooth display should be maximized with evaluation of lips at rest and the "E" smile, and modulated by functional and phonetic parameters.[5,6]

- With the lips at rest, a youthful appearance of an unworn dentition will display 2 to 4 mm of the incisal aspect of the central incisors **(Fig 2)**.[7]
- When the patient says "E" while deliberately smiling, the incisal edges of the maxillary centrals should comfortably be positioned 50% to 70% down from the spaced defined by the upper and lower lip **(Fig 3)**.[6]

3. Evaluation of the incisal plane to the occlusal plane in the lateral view can be useful. The centrals are most likely too short if their incisal surface is above the occlusal plane, and they may be too long if their incisal surface is below the occlusal plane.
4. There are commonly accepted standards of the width-to-length proportions of central incisors that are deemed to be esthetic. Ideally, the width of the central is 75-80% of its length.
5. Central length is made to approximate 1/16 of facial length. A commercially available "tooth indicator" facilitates such a conversion. Although not a universally accepted design criterion, some practitioners consider it a good starting point.[8]

In the end, it is the judgment of the restoring dentist to create harmony and balance through evaluation and alteration of provisionals rather than rigid adherence to a mathematical formula. If the prescribed parameters cannot meet the desired esthetic result, the clinician should consider other potential orthodontic or orthognathic treatment options.

INCISAL EDGE POSITION

The incisal edge position (IEP) of the central incisors is the cornerstone from which all smile design is initiated. This position needs to take into consideration both functional and esthetic parameters that will be unique to every patient. The smile from an anterior superior angle and in profile will aid in the illustration of this relationship **(Fig 4)**.[9,10]

Only after the incisal edge position of the centrals has been determined can the length, contours, and proportions of the proposed restored teeth be designed. From the occlusal view, the incisal edge should be definitive and clear and not a rolled landmark.

Figure 2: The "rest position" should reveal 2-4 mm of tooth structure in a youthful smile.

Figure 3: The "E" smile gives the clinician an indication of the relative lip mobility and the vertical position of the maxillary incisal edge relative to the lip drape.

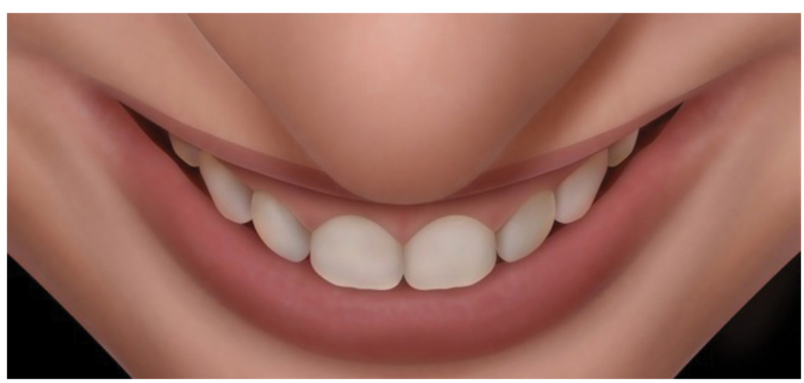
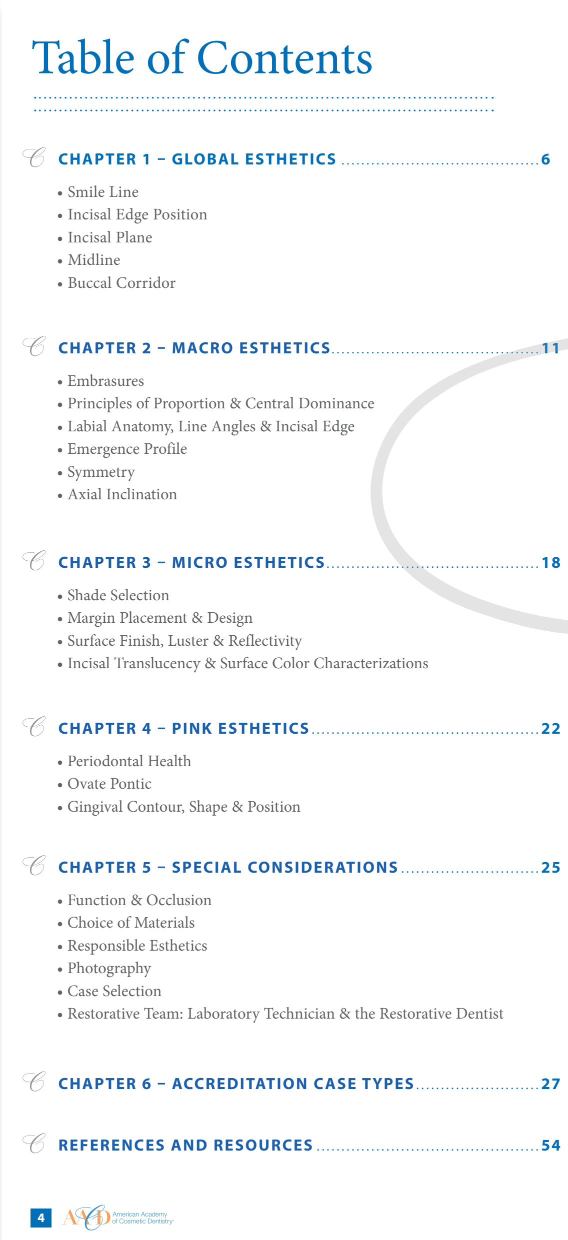


Figure 4: The "tipped down smile" is taken at a 45° angle to the occlusal plane. The maxillary edge of the central incisors should fall within the wet-dry line of the lower lip to facilitate the lip closure path.



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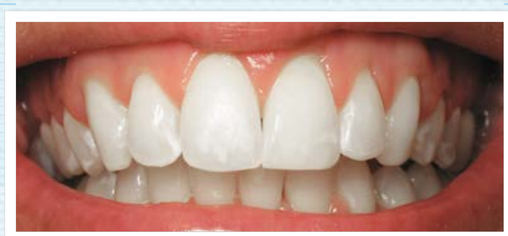

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