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Dear readers,

The concept of aesthetic and cosmetic dentistry has evolved during last several years, involving other new concepts and trends in dentistry. At aesthetic dentistry congresses all over the world, the topics are involving concepts of minimally invasive dentistry and focusing on the differences between analogue and digital workflows. Implant placement in the aesthetic zone and soft-tissue manipulation for achieving aesthetic results are mandatory subjects among the invited speakers. A broad range of topics are taken into consideration when the scientific committee decides on the invited speakers and topics.

The same situation applies to publications in aesthetic and cosmetic dentistry. In this issue of *cosmetic dentistry*, the authors have approached the same concepts: minimal invasiveness in a case report of total rehabilitation in centric relation combining indirect and direct restorative solutions; looking at digital versus analogue in a case report on ceramic veneers in the anterior region; minimally invasive prosthetic procedures and digital solutions for treatment planning.

I am very pleased that this issue of *cosmetic dentistry* will be distributed at the 15th annual meeting of the European Society of Cosmetic Dentistry (ESCD), which is being held in Lisbon in Portugal on 20 to 22 September. It is gratifying that many of the authors in this *cosmetic dentistry* issue are founding or active members of the ESCD, or invited speakers to the congress.

This anniversary edition of the ESCD meeting will really be an outstanding one according to the complexity of organisation and number of participants (more than 600). There will be two main podiums and two parallel hands-on sessions over the three days. For the first time at the event, there will be a live TV studio, from where interviews with speakers, participants, members of the industry and organisers will be broadcast live on ESCD’s Facebook page. For those unable to come to Lisbon, we offer the possibility of viewing the scientific sessions online.

Self-registration will make the registration process a smooth one and the social programme throughout the event (ESCD & Friends, president’s dinner, Portuguese night) will foster further cohesion among the members of our society.

I wish you all an instructive read and that you will be inspired by the topics addressed and be able to implement the methods in your day-to-day practice. I also wish you three days of science and pleasure in Lisbon, together with the ESCD and the Dental Tribune International family.

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Minimally invasive prosthetic procedures

Nowadays, the demand for prosthetic treatments owing to imperfect teeth is steadily rising. The importance given to aesthetics in our society is growing, especially among young people, and clinicians ought to be increasingly conservative in their treatments and take precautionary measures.

This type of approach allows the dentist to maintain most of the remaining dental structure while re-establishing a proper relationship between function, aesthetics, and duration of the prosthetic restoration. Minimising the removal of enamel while aiming to satisfy the aesthetic expectations of the patient represents a risk for the clinician, especially when the remaining tooth structure is already partly worn. When treating a case extending to both arches with a severely worn dentition, the goal of the clinician should be to obtain micromechanical retention and mechanical strength though paradoxically limiting the amount of tooth preparation.

By preserving the maximum amount of enamel, the clinician will be able to reduce occlusal ceramic thickness without compromising the resistance and aesthetic result of the restoration. The use of a minimally invasive prosthetic procedure (MIPP) will help the dentist to reduce the biological cost of enamel removal. The key steps of this technique are the following:

1. Increase the vertical dimension of occlusion (VDO);
2. reduce the thickness of the monolithic ceramic material;
3. preserve the enamel during tooth preparation;
4. adhesively bond the restorations.

1. Increase of the vertical dimension of occlusion

In prosthetic restorations extended to at least one full arch, an increase in the VDO of the patient is important in order to achieve a successful aesthetic and functional and restorative result. This procedure will help the clinician to reduce the amount of dental tissue removed in conventional preparation. By increasing the VDO, the clinician will be able to avoid invasive dental and occlusal preparation and thus be able to bond the ceramic restoration to the remaining enamel. A permanent increase in the VDO is a safe and predictable procedure if done up to 5 mm (considering the absence of disease affecting the temporo-mandibular joint and the presence of correct disc alignment); in any case, any discomfort related to the patient’s new VDO ratio will last no longer than one to two weeks.

When determining a modification in the VDO vertical dimension, the clinician may consider the use of the following techniques:

– Evaluation of the required space for restorative material;
– interocclusal rest space;
– evaluation of the facial proportions;
– phonetics (“m” and “s” sounds); and
– acrylic preoperative mock-up.

Among these techniques, the one most effective in order to gain acceptance of the new VDO by the patient is the evaluation of speech, particularly with regard to sibilants or “s” sounds.
2. Reduction of the thickness of the monolithic ceramic material

The reduction in the thickness of the ceramic material used in the restoration is a great advantage of the MIPP technique. It has been proven that minimally invasive lithium disilicate occlusal restorations, if supported by enamel, have a high load-bearing capacity and therefore a high resistance to fracture. The key to the success of the restoration is its adhesive bonding, which must always be on enamel and involve an etchable ceramic material.

3. Preservation of enamel during tooth preparation

The preservation of enamel during tooth preparation is highly important in order to implement the MIPP technique. The recommended conventional thickness in the occlusal area for porcelain restorations is 1.5 to 2 mm; however, these values can be reduced by using an etchable monolithic ceramic material with a decreased thickness bonded to enamel.

4. Adhesive bonding of the restorations

Adhesion to enamel can influence the design of the tooth preparation, allowing the clinician to maintain the maximum amount of dental structure and thereby achieve excellent treatment results, including lower post-cementation sensitivity, improved support of the ceramic restoration and avoidance of endodontic intervention. Moreover, a correctly performed adhesive procedure can eliminate the need for extensive tooth preparation, as well as the use of anaesthesia. Success will depend on the ability to establish good adhesion between the tooth structure and the porcelain with correct performance of the etching procedure and appropriate use of adhesive materials.

The MIPP technique is characterised into six different classifications, which can be divided into two main approaches:

1. Confirmatory approach when the patient’s occlusion is left in maximum intercuspation:
   - MIPP 0: additional restorations (anterior, posterior) with no preparation, mainly on enamel
   - MIPP 1: partial restorations (anterior veneers, posterior restorations) with minimal tooth preparation, mainly on enamel

2. Reorganisation approach in the case of a modification of the VDO and centric relation (CR):
   - MIPP 2A: partial restorations (veneers, posterior restorations) with minimal tooth preparation, mainly on enamel in CR
   - MIPP 2B: full-coverage veneers (patient with open bite in CR) with minimal tooth preparation, mainly on enamel
– MIPP 3A: one arch in CR with VDO alteration and tooth structure preservation, mainly on enamel
– MIPP 3B: two arches in CR with VDO alteration and tooth structure preservation, mainly on enamel

The use of the MIPP technique in prosthetic restorations aids the clinician in achieving excellent functional and aesthetic results, avoiding invasiveness in the reduction of the tooth structure and thus allowing a more physiological occlusion and a better distribution of occlusal forces.

New digital tools for the treatment plan: Guided Esthetic Treatment App

The need of clinicians all over the world for a tool that supports them in formulation of the correct treatment plan, combined with new technologies that simplify and accelerate many prosthetic procedures, led us to develop a multimedia application that assists the dentist in all of the phases of data collection and analysis. This app is designed to interact with other available technological tools (such as new-generation 3-D face scanners), thus
facilitating an entirely digital workflow for prosthetic rehabilitation.

The GETApp (Guided Esthetic Treatment App) was developed according to the systematic approach to data collection created by Dr Mauro Fradeani. The app automatically analyses all of the values and information on the patient collected by the clinician to determine the best possible treatment to be chosen. The user can modify the suggested treatment plan at any time, by adapting the selected parameters according to his or her specific needs.

The tool guides the dentist step by step through the complete decision-making process, aiding him or her in achieving optimal aesthetic and functional results. The two main phases of data collection and processing offer detailed clinical explanations, which contribute to making GETApp a modern educational system for both simple and complex prosthetic rehabilitation.

By the clinician following all of the suggested steps and entering all of the requested values and parameters, the app automatically generates a PDF file containing all of the information provided by the clinician. This allows him or her to easily share with the dental laboratory every detail for the fabrication of the ideal prosthetic work.

In conclusion, the benefits and possibilities provided by the GETApp to the clinician are as follows:

– Collection of data for patient anamnesis (the GETApp system can replace the medical records);
– Collection of all of the clinical data necessary for good communication with the dental team (radiographs, periodontal chart, health of each tooth, tooth colour, previous dental treatments to be redone, stomatognathic dysfunction);
– Guided and predictable method for dental photography and case documentation;
– Collection of all aesthetic and functional values necessary for formulation of the treatment plan;
– Complete and automated support in formulation of the treatment plan;
– Effective communication with the dental laboratory; and
– Effective communication with the patient.

Innovative operative protocols such as the MIPP, combined with the use of modern digital systems such as the GETApp, represent a revolution in the approach to prosthetic treatment. These new procedures will undoubtedly help the clinician to confidently perform comprehensive treatments involving dentures, crowns and veneers on natural dentition and implants, from simple to complex full-mouth rehabilitation.

About

In 1979, Dr Fradeani graduated in medicine and surgery from the University of Ancona (now the Università Politecnica delle Marche), Italy, where he then completed a specialisation in dentistry in 1983. He is a past President of the European Academy of Esthetic Dentistry (2003/2004) and of the Accademia Italiana di Odontoiatria Protesica (1999/2000), and was a visiting associate professor in prosthetics at Louisiana State University, New Orleans, US, from 1999 to 2008. He is an active member of the American Academy of Esthetic Dentistry and maintains membership of the American Academy of Fixed Prosthodontics. He is the founder and Director of the ACE Institute in Pesaro, Italy. He is also the founder and Director of Fradeani Education, an educational project developed together with a group of expert speakers with the goal of promoting an Italian model of excellence in dentistry throughout the world. He is the author of the two-volume series Esthetic Rehabilitation in Fixed Prosthodontics, translated into 11 languages (Quintessence, 2004 and 2008). He runs a private practice in Pesaro limited to prostheses on natural dentition and implants.
Introduction

The communication between dentist and patient is important, especially in cases of partial or complete aesthetic restoration in the anterior (smile makeover). Nowadays, it is important not only to treat oral pathology, but also to request an aesthetic evaluation of the patient’s smile to obtain results that respect the patient’s aesthetic expectation. The smile is our business card and represents the first thing that distinguishes us in human relationships, in work and in social life. It is necessary to know that a smile can appear unpleasant even if there are no evident issues or pathology, influencing people/patients’ psychologically. The clinician should understand the psychological needs of desire, perception and personality to explain in a better way the necessary therapeutics and/or aesthetic choices. When a smile is being designed, these parameters are fundamental and dependent on the communication with the patient and they should be considered in the evaluation of a 360° clinical approach. It often happens that patients are not able to identify their expectations, so dentists must be able to consider whether their exigencies can be satisfied.

What does the clinician need to plan an aesthetic dentistry treatment? What is needed to plan a smile that is integrated into the face? The diagnostic history of each clinical case must include anamnesis, analogue and digital clinical models, radiographic examination, intraoral and extraoral photographs, functional analysis, aesthetic dentofacial analysis, intraoral diagnosis, static analysis and 3-D reconstruction of the smile design. Nowadays, in the field of dental aesthetics, virtual planning is more and more used. The clinician can interact with the software for virtual planning, in order to simulate and show to the patient the expected result. Virtual planning is particularly important when patients have expressed a strong desire for a perfect smile.
and dynamic extraoral diagnosis, the psychological approach to the patient and informed consent.

Of benefit for the clinician, regarding the patient, is to employ intuitive language in taking a subtle approach to the patient, and he or she must subject himself or herself to the expertise of aesthetic dentistry to become the real protagonist of aesthetic dentistry. As patients’ requests mainly relate to aesthetics, we must depend on the definition of “aesthetic smile” to know how to apply it appropriately. Is there a concept of “beauty” achievable in aesthetic dentistry? In our opinion, a smile cannot lose its meaning, attraction and personality; therefore, it has psychological, sociological and communicative involvement. Only through effective communication can we answer to the needs of the evolution of the past 50 years. Today, it is easy and possible to communicate regarding aesthetics, owing to the instant availability of the digital image and since the image is a universal language, easy, immediate and decoded.

With the progress of technology and the introduction of digital photography, programme and protocols have been introduced to facilitate communication increasingly through the preview of the treatment result that the patient will receive (smile design or oral design). More generally, Digital Smile Design (developed by Dr Christian Coachman) allows the use of presentation software (Keynote, Apple, or PowerPoint, Microsoft) or software specifically dedicated to dentistry. In addition to these, regarding 2-D aesthetic pre-visualisation, it is possible to use image editing software, such as Photoshop Smile Design as described by Dr Edward McLaren and Aesthetic Digital Smile Design (ADSD) by Dr Valerio Bini.

A detailed smile analysis and its design are fundamental parts of this method and indispensable for the formulation of the treatment plan for the clinical case. The first step involves the acquisition of images and video (static and dynamic dentofacial) on the basis of the ADSD protocol (Figs. 1–3). The import of these important elements into the aesthetic digital file of the patient is complementary to the anamnesis because they are integral to the objective intra- and extraoral examination.
The second step involves the aesthetic analysis according to the main guidelines. Dynamic smile analysis and dentolabial phonetic analysis are identified in their characteristics through recording images caught during sleep, speaking and smiling, allowing better understanding of the variation of the soft perioral tissue.

Nowadays, digital technology is a successful reality and a confirmed part of daily life in wider society; consequently, the digital workflow in dentistry has become suitable for all professionals.

Aesthetic Digital Smile Design

The dentist must communicate and explain to the patient how the smile can be improved and personalised; therefore, it is necessary pre-visualise the outcome of an ideal aesthetic treatment to show it to the patient using images.

In order to satisfy the exigencies of both the patient and the team in a clinical case, the methodology of ADSD allows the clinician to analyse and provide an indication of the dimensional and morphological aesthetics of the tooth volume, starting from the acquisition of 2-D elements useful to the aesthetic analysis through photographs, an instrument we can all have in our clinic. The smile design digitally realised in 2-D offers the ability to obtain new and predictable compositions of aesthetic tooth design using images in 2-D with visual perception in 3-D (picture-in-picture). Digi-
tal processing of the images can be done in different ways according to the exigencies of the smile designer; currently ADSD can be executed using the well-known graphics editing programme Adobe Photoshop CC (Adobe Systems).

ADSD uses a particular set-up dedicated to the smile designer, through which it is possible to use this well-designed software in a simple way by the dental team. The ADSD method provides a photographic result that as far as possible reflects the clinical reality. Forms, colours, disposition and aesthetic dental composition are inseparable from the aesthetic facial composition. They perform a primary role through the 3-D visual perception that the digital dental image editing yields. Once the images have been imported into the work area of the software, the frontal and lateral photographs (digital orthogonal projection planning) are aligned to develop the dentofacial mapping related to all its main components (ADSD digital face mapping; Figs. 4 & 5).

Through the visual information provided, the smile design or oral design is a useful way to communicate to the patient the envisioned aesthetic dental composition of the smile, synonymous with predictability. This offers a great instrument for communication in a 360° clinical approach, especially with the dental team. The modelling and placement confer the aspect and the visual 3-D perception of the tooth morphology that the dental team will copy in the CAD modelling phase (Fig. 6).

3-D modelling

In aesthetic dentistry, the role of 3-D has begun to assume greater importance both in the optimisation of the clinical workflow and as an important improvement to the efficiency in communication between dentist and patient. 3-D modelling is a technical discipline that provides the virtual reconstruction in 3-D of an object in the real world. This discipline, which has its origins in architecture and design, is used in unusual contexts, such...
as biomedical field. Dentistry was the first discipline to use 3-D modelling as an instrument perfectly integrated into the work process. Other medical disciplines followed and now this technique is frequently used in clinical and research contexts.

Because of this, smile design could be defined as dental specialisation that can certainly use 3-D as a significant instrument of support for a large part of clinical and diagnostic activity. 3-D in smile design overcomes all of the limits of 2-D technology. Currently, 3-D permits the user to select teeth from a 3-D library, available in commercial software, or to realise a personal database starting from an intraoral scan (Figs. 7a & b).

The advantage that 3-D technology certainly can offer is relevant: it allows the design of patient-specific teeth directly in 3-D, allowing quick access to all production systems, including rapid prototyping. There are many software programmes available that facilitate working in 3-D, and among these, there is one that is appreciated for a series of characteristics that are different from the others, such as its ease of use, being entirely free of charge and its infinite versatility. The factotum software is called Meshmixer and is from Autodesk, a leader in 3-D software. It allows the designer to work at 360° on the mesh, generating an infinite series of modification (Figs. 8a–e).

3-D prototype

An important improvement to the workflow of smile design is the printing of prototypes with the new 3-D printers, facilitating an increase in the efficiency in the modality of communication between dentist and patient. From a clinical point of view, dentistry, more than the others, is a discipline that permits a very concrete and realistic use of 3-D printing. There are different printing technologies now available, but in dentistry, the technologies mainly used are stereolithography (SLA) and PolyJet (Stratasys).

SLA is a printing technology that uses photosensitive resin to produce physical objects through the use of laser light. This photosensitive resin contains photoinitiators, such as particular molecules that polymerise if exposed to a luminous ray of a certain wavelength. A sub-group of SLA is digital light processing (DLP), a technology that uses light to polymerise resins as well, but the luminous source is the beam emitted from a projector in LED (not laser).
PolyJet technology ejects drops of resin from nozzles on to the build tray and the resin is polymerised by a dif-
fused light of a determinate wavelength. Unlike SLA tech-
nology, PolyJet makes use of high-cost machinery with-
out providing added value considering that the same is
obtainable with some low-cost technologies. Owing to our
experience, we prefer to utilise an SLA printer to realise a
3-D resin model, and based on this, a silicone key (neg-
tive reproduction) is fabricated, then we place the acrylic
resin into the silicone key and thereafter insert it into the
patient’s mouth and wait until it solidifies. In the meantime,
we remove any excess material from the silicone key. After
polymerisation, we remove the silicone key and finish the
resin plate as best we can. Once these steps have been
completed, we show to the patient our vision of the aes-
thetics of his or her smile, based on our earlier analysis
with digital analysis of photographs and successively pro-
totyped in 3-D simulated in his or her mouth, and we eval-
uate with him or her the envisioned final result (Figs. 9a–d).

Discussion

In our opinion, photography provides the ideal mor-
phological indication of the new smile that should be
communicated to the patient. With ADSD 2-D method-
ology, we obtain some indication useful also for the team
that can develop, through 3-D modelling, a prototype sil-
icone key to test in the mouth with resin. The purpose of
aesthetic pre-visualisation with ADSD is to demonstrate
to the patient what we can obtain from the aesthetic
analysis of photographs and the possible treatment plan
(Figs. 10a–i). The problem today, in this communication
with 3-D, is the absence of a texture that looks similar to
that of the natural dentition, so when the model is shown
to the patient, it may evoke a negative reaction owing to
what may appear to be a very poor integration. Such vi-
sualisation of a natural texture can at present be obtained
only with photography (Figs. 11a & b).

Conclusion

A series of technical procedures have been proposed
that involve digital smile design, ranging from 2-D to 3-D.
This article has described an alternative method for a
3-D model that is cost-effective and reproducible to ob-
tain a prototype from a digital photograph of the smile.
Meshmixer software for 3-D design has the advantage of
being open source and using it requires minimal learning.
Moreover, with Meshmixer, one can create in an easy way
a personal digital dental database complementary to the
2-D library. The database can be modified following the
rules of smile design that has as its purpose 3-D printing of
a model in resin characterised by high accuracy of details.

This article originally appeared in DT France 6&7/2018.

about

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Introduction

Different materials and treatment options are available in aesthetic and restorative dentistry for the anterior region. The conventional protocol, including an analogue impression with polyether or polyvinylsiloxane, a master cast and die fabrication, waxing and pressing of ceramic materials, requires exceptional skills and is technique-sensitive. Intraoral scanning and digital impression taking provide an accurate alternative method for transferring information from the mouth to the dental laboratory. The digital file is always on the computer and can be immediately processed or at any time, unlike with the conventional procedure.

Regarding materials, various newer products, such as pressed or milled ceramics, offer enhanced strength and functionality; however, in thinner dimensions, they lack the inherent aesthetic beauty of conventional materials such as feldspathic porcelain. As patient demand for better aesthetics has increased in recent years so too has the need for restorative materials that closely mimic the patient’s natural dentition. Initially used for the creation of porcelain dentures, feldspathic porcelain has emerged as the premier aesthetic material for custom veneer restorations. In recent years, the use of hand-layered powder/liquid feldspathic porcelain has been revived based on its highly aesthetic values and little to no preparation requirements. By keeping preparation to a minimum, less tooth structure is removed and procedures are much less invasive, which is exactly what patients desire.

Digital vs. analogue workflow on ten ceramic veneers in the maxilla

Dr Michalis Diomataris, Dr Stavros Pelekanos & Michalis Papastamos, Greece

Fig. 1: Initial photograph of the anterior teeth prior to orthodontic treatment.
Fig. 2a: Anterior teeth after orthodontic treatment. Fig. 2b: Extraoral photographs after orthodontic treatment.

Fig. 3: Digital smile design indicating crown lengthening of teeth #13, 12, 11 and 21 and restorative treatment of the ten anterior teeth.
Fig. 4: Wax-up on the stone model concerning the restorative treatment of the ten anterior teeth.
Fig. 5: Three-dimensionally printed model of the digital smile design planning, bearing a mock-up shell. A cervical opening was introduced for surgical access and guidance for crown lengthening.
Fig. 6a & b: Intraoral fit of the surgical guide for crown lengthening.
Fig. 7: Periodontal tissue of the anterior teeth six months after crown lengthening.
In contrast, the conventional methods of ceramic fabrication have been described as time-consuming, technique-sensitive and unpredictable owing to the many variables, and thus CAD/CAM may be a good alternative for both dentists and laboratories.\(^3\) CAD/CAM may also reduce the fabrication time of high-strength ceramics by up to 90 per cent.\(^1\) Furthermore, industrially fabricated blocks are more homogenous, with minimal flaws, and CAD/CAM restorations have been found to compare favourably with other restorative options.\(^4, 5\)

As far as optical properties and CAD/CAM are concerned, the fact of complex optical illusion phenomena in anterior aesthetics cannot always be met with monochromatic aesthetic materials without the need for final characterisation by a dental technician. In order to overcome such aesthetic disadvantages of a monochromatic restoration, multichromatic ceramic blocks have been developed to create a 3-D layered structure. These ceramic blocks offer a gradient of chroma from the cervical to the incisal areas that replicate dentine and enamel in the same block.\(^6-8\)

The aim of this case report is to compare the analogue versus the digital workflow on ten ceramic veneers in the maxilla, in terms of aesthetic outcome, length of procedures and technical sensitivity for both the dentist and the dental technician.

---

**Fig. 8a:** Mock-up silicone index. **Fig. 8b:** Intraoral photograph of the mock-up. **Fig. 9a:** Preparation through the mock-up. **Fig. 9b:** Check of the preparation depth, with the use of the silicone guide, palatal aspect. **Fig. 9c:** Final preparation of the teeth. **Fig. 10:** Analogue impression with polyvinylsiloxane. **Fig. 11:** Digital impression with TRIOS. **Fig. 12a:** Digital planning of the provisional restorations. **Fig. 12b:** Provisional restorations intraorally (Telio CAD). **Fig. 13:** Analogue workflow (refractory dies, built-up veneers, adjustments, staining/glazing). **Fig. 14:** Digital workflow (3-D printed model, CAD/CAM veneers, adjustments, staining/glazing).

**Fig. 15a:** Feldspathic veneers with try-in paste. **Fig. 15b:** CAD/CAM veneers with try-in paste. **Fig. 15c:** First quadrant feldspathic veneers and second quadrant CAD/CAM veneers simultaneously with try-in paste.
A 35-year-old patient presented at the office with the chief desire that the aesthetics in the anterior region be changed (Fig. 1). A diagnostic wax-up was performed, followed by mock-up fabrication, in order to obtain a preliminary visualisation of the final outcome. Orthodontic treatment was proposed in order to align the teeth in a more favourable position for veneers requiring minimal preparation and to reduce the overbite. One year after treatment, the patient returned for the final prosthetic rehabilitation (Figs. 2a & b).

Case report

A 35-year-old patient presented at the office with the chief desire that the aesthetics in the anterior region be changed (Fig. 1). A diagnostic wax-up was performed, followed by mock-up fabrication, in order to obtain a preliminary visualisation of the final outcome. Orthodontic treatment was proposed in order to align the teeth in a more favourable position for veneers requiring minimal preparation and to reduce the overbite. One year after treatment, the patient returned for the final prosthetic rehabilitation (Figs. 2a & b).

Methods and materials

Digital smile design according to Coachman and Calamita9 was performed, from which a treatment plan of crown lengthening and veneers on teeth #15–25 (Fig. 3) was proposed. A conventional diagnostic wax-up was also produced (Fig. 4). Both digital and conventional mock-ups were applied, and agreement was attained concerning tooth shapes and proportions. Crown lengthening was performed, guided by the digital mock-up, with the use of an acrylic transparent double crown lengthening guide that indicated the borders of the gingivectomy and alveolectomy needed in periodontal surgery for aesthetic rehabilitation (Figs. 5 & 6).10

After six months of tissue stabilisation (Fig. 7), a mock-up was produced with Telio CS C&B (Ivoclar Vivadent) chairside (Figs. 8a & b), and tooth preparations with silicone guides were performed (Figs. 9a–c). Both conventional impressions with polyvinylsiloxane (Fig. 10) and digital impressions (TRIOS, 3Shape) were taken (Fig. 11).

Provisionalisation was executed digitally, using Telio CAD (Ivoclar Vivadent) in the Wieland Select CNC milling machine. The design was performed with the 3Shape DentalDesigner 2015 software (Figs. 12a & b). Two sets of final restorations were fabricated. The set of feldspathic veneers was fabricated on a stone model using IPS Style (Ivoclar Vivadent), while IPS Empress CAD Multi (Ivoclar Vivadent) was used for the digital set (Figs. 13 & 14). Both sets were examined intraorally with a try-in paste to compare the optical properties of the feldspathic and the CAD/CAM veneers (Figs. 15a–c).

The subjective decision of the clinician and the patient was to cement the feldspathic veneers, owing to slight differences in the length...
of the central incisors between the two sets. Adhesive procedures followed (Figs. 16a–f), and final intraoral and extraoral photographs were captured one week later (Figs. 17a–e).

Results

Intraoral digital scanning is a perfect alternative clinical procedure compared with the conventional impression technique. The digital planning and mock-up procedure is a powerful communication tool for the dentist, although special skills in using computer software are required. Regarding the laboratory workflow, most of the analogue procedures require more time (refractory dies, built-up veneers, adjustments), except the staining/glazing (Figs. 18a & b). Although the aesthetic outcome of the feldspathic veneers was subjectively chosen in this case, the analogue workflow is much more demanding. The digital approach, because of the reduced difficulty, speed, complexity and patient discomfort, tends to be preferable (Figs. 18a & b).

Conclusion

Knowledge and application of virtual smile design procedures, coupled with innovative dental laboratory technologies, allow dentists to diagnose, plan, create and deliver aesthetically pleasing new dental compositions. Furthermore, advances in CAD/CAM technology have catalysed the development of aesthetic veneer restorations with industrially produced materials possessing superior biomechanical properties and good aesthetics.

about

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Introduction

This article describes a case in which severe tooth damage was presented and complex oral rehabilitation was planned. Part of the rehabilitation had been completed more than a decade before, and the rest only recently. Although there was only ten years between these two treatments (upper arch in 2005 and lower arch in 2015), a significant paradigm shift was evident concerning the treatment planning and with respect to the amount of tooth reduction.

Case report

A 25-year-old female patient reported to the dental office 12 years ago in order to improve her smile (Figs. 1–3). Her anterior maxillary and mandibular teeth were severely damaged owing to a past chronic eating disorder. In 2005, complex oral rehabilitation was planned for the patient, starting from the upper arch. For the maxillary posterior teeth, full-ceramic onlays were planned and placed, while for the maxillary anterior teeth, full-ceramic crowns were fabricated (Figs. 4–6). A decade ago, this
was the standard procedure in such a case of structural damage.

The patient, happy with the appearance of the maxillary teeth when smiling, did not present for the completion of the complex rehabilitation until 2015. During the past ten years, some of the full-porcelain crowns had sustained minor chipping (Figs. 7–9), which was a result of the unfinished rehabilitation. After a decade of advances in dental technology and treatment planning, we could propose to the patient a new option, one that was minimally invasive and without the extent of tooth reduction associated with the work carried out ten years earlier.

Treatment planning

The Kois deprogrammer was employed in order to register the centric relation and articulate the models in this position. A wax-up of the lower arch was obtained, and the vertical dimension of occlusion (VDO) was slightly increased, based on aesthetic analysis. The obvious benefit of the VDO increase was also the fact that there would then be enough space for the restorative material without additional tooth reduction. The appropriate mock-up procedure and phonetic analysis were performed to confirm this. In the posterior area, lithium disilicate onlays were used, while direct composite resins were planned for the anterior teeth.

Restorative phase: Posterior teeth

For the mandibular posterior teeth, minimally invasive preparation took place, generally only in order to produce sharp, visible borders for the laboratory preparation procedures. The entire preparation surface was meticulously polished, with the exception of the borders, to remain sharp and evident for the dental technician. In order to ensure sufficient occlusal volume for the restorative space, a pattern resin jig was fabricated on the articulated study models with increased VDO and transferred to the mouth for control (Fig. 10). Impressions were taken, and the lithium disilicate (IPS e.max, Ivoclar...
Vivadent onlays were fabricated in the laboratory (Fig. 11). At the next appointment, the onlays were tried in for correct marginal adaptation and adhesively luted under rubber dam isolation (Figs. 12–20).

Restorative phase: Anterior teeth

The teeth were cleaned with pumice, and the incisal parts were abraded with 50 µ aluminium oxide particles. On the incisal vestibular edge, a 1 mm chamfer was obtained using a diamond ball tip (001-006-2, Olident), and the lower part of the chamfer was delicately elongated using an 80° bevel (around 0.5 mm; Figs. 21 & 22). The mandibular anterior teeth were found to be tight and crowded; consequently, the operator found it easier to restore the teeth without rubber dam isolation.

The enamel and dentine were etched with 38% phosphoric acid for 20 seconds, then OlIBOND adhesive (a fifth-generation prime and bond adhesive, Olident) was meticulously applied to the dentine and enamel, rinsed with water, air-dried and light-cured for 20 seconds.

The restorative phase of the anterior teeth consisted of creating an external box, placing inside a layer of inner composite followed by a final outer composite layer. The procedure does not have to be too complex to
achieve a predictable result; one can obtain correct layering with only two syringes of composite resin (Fig. 23).

Based on the wax-up (Fig. 24), a silicone index was made and cut in the frontal plane. With the lingual part of the index, the back shell of the reconstruction was created using a thin layer of nano-filler composite (OliREVO, Shade A3, Olident). In the next stage, the approximal surfaces were built up with the same composite material, and by means of the BlueView VariStrip (Garrison), which provides an anatomical shape mesially and distally (Figs. 25a & 26). When all of the boxes had been prepared, the inner, more opaque layer (OliREVO, Shade OA2) was applied, and the mamelons were shaped before polymerisation in order to create natural internal characterisation (Figs. 25b, 27 & 28). The inner layer was polymerised, and finally the outer layer of composite (OliREVO, Shade OA2) was applied in a thickness of more or less 0.5 mm (Figs. 25c & 29). This layer was meticulously brushed with the modelling brush and finally polymerised with slight time extension (40 seconds for each of the surfaces). After minor bite corrections, the final characterisation was done. First, the primary anatomy was achieved by contouring the transition angles and incisal edge. The next step was to start reproducing the secondary anatomy: the division of the lobes. These were drawn in pencil (Fig. 30) and formed with a diamond bur (831-204-012, Komet Dental/Brasseler; Fig. 23). Next, a rubber point was used to smooth the rough surface left by the bur. The rubber point was also used to give an initial gloss to the restoration. The restoration was polished with 1 µm diamond paste applied with a natural goat hair brush used at 1,000 to 10,000 rpm.

The satisfactory clinical result of the lower arch restorative rehabilitation can be seen in Figures 31 to 33. The 24-month clinical control showed excellent clinical behaviour with respect to the lithium disilicate onlays and anterior composite resin restorations (Fig. 34).

Conclusion

By increasing the VDO, it is possible to achieve additional space for the restoration, and in this way to minimise the tooth reduction and maximise the adhesion owing to residual enamel. Correct treatment planning and utilisation of a wax-up and silicone index allow predictable results for the final shape and shade of the composite restoration.

contact

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Introduction

Discolouration of teeth is a common aesthetic problem and bleaching is the most conservative treatment option when compared to other restorative techniques used to change tooth colour. The mechanism of the bleaching process is based on the penetration of different oxygen radicals, which occurs during the decomposition of hydrogen peroxide (H₂O₂) into discoloured dentine, thus modifying the dentine colourant molecules through an oxidation reaction. Most of the in-office bleaching gels contain hydrogen peroxide and these agents are frequently used with an activator such as heat or light. Light sources accelerate the bleaching procedure by heating the bleaching gels to increase the decomposition rate of oxygen to oxygen-free radicals and raise the release of stained molecules. The Er:YAG laser wavelength has been described as a safe and effective light source option for office bleaching treatment. TouchWhite patented tooth whitening makes use of the fact that the Er:YAG laser wavelength has an absorption peak in water, which is the major component of aqueous bleaching gels. This eliminates the need for any additional absorbing particles in the bleaching gels. More importantly, taking into account thermal burden considerations, the TouchWhite procedure represents the most effective and least invasive laser whitening...
Due to its high absorption in bleaching gels, the Er:YAG laser beam is fully absorbed in the gel and does not penetrate to the hard tissue or the pulp. All of the laser energy is thus effectively used for the heating of the gel. There is no direct heating of the dental tissue and the pulp, as is the case with other laser-assisted whitening methods. There is also no risk of accidentally damaging the hard dental tissue as the laser fluence of every laser pulse is set significantly below the ablation threshold for dental tissues. As a consequence, the procedure can be performed with a minimal undesirable thermal burden on the tooth and the tooth whitening speed can be safely increased by 5 to 10 times.1, 4

Case report

A male patient in his late thirties suffered a sporting accident some fifteen years ago that left his upper left central incisor with necrotic pulp, which discoloured after root canal therapy. The aim of treatment was to lighten the tooth colour in preparation for a ceramic veneer using the TouchWhite protocol (LightWalker laser system, Fotona).

Treatment

The palatal resin restoration was removed. The GP was removed to the cervical dentine level. A layer of GIC lining was placed to protect the cervical dentine. Clear hydrogen peroxide (35%) was used as the bleaching gel. The Fotona TouchWhite protocol was used to activate the bleaching process. We used the R16 hand-piece with the following parameters: VLP, 0.75 W, 10 Hz. The gel was placed in the pulpal chamber and on the labial surface. The laser beam alternatively activated the gel for 20 seconds on the labial surface and on the pulpal chamber (three applications on each side). The gel was washed off and replaced with a fresh gel coating before administering another three applications. The discoloration subsided significantly after six activations. Before the session ended a cotton pellet soaked with bleaching gel was placed in the pulpal chamber. It was activated three times, each time for 20 seconds with 20 seconds rest in between activations. A temporary restoration was placed with the cotton pellet remaining in the chamber.

Result

The treatment was reviewed after 18 days showing a complete recovery. The palatal composite resin was placed and the patient no longer needed a ceramic veneer. Many factors contributed to a successful result:

1. A high concentration bleaching gel with higher pH.
2. The optimum level laser energy provided.
3. Adequate removal of the lining/GP (to the cervical dentine).
4. Activated bleaching gel left in the pulpal chamber to continue working.3

TouchWhite Er:YAG teeth bleaching can be a safe and effective teeth whitening method for vital and non-vital tooth discolouration.

References

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Age-appropriate aesthetics
Creating natural effects with VITA VM materials

Carolin Wehning, Germany

Assessment and planning

A 77-year-old patient presented to the dental practice after a coronal transverse fracture of tooth #21 that had already been treated with a direct composite. Clinically, the results were morphologically and aesthetically inadequate (Fig. 1). On the adjacent natural tooth (#11), age-related discolorations, initial white and brown spot lesions in the cervical area, and a vestibular transverse dark-brown crack were apparent. The dentist and patient decided on restoration of the tooth with a full-ceramic crown for long-term stabilisation, on which...
the colour effect of tooth #11 was to be reproduced in detail. In order to achieve a predictable result, the situation was moulded and a model was developed for a wax-up. Tooth #21 was prepared for a full crown and a master model was produced using a precision mould (Fig. 2).

CAD/CAM fabrication and veneering

The crown framework was made of CAD/CAM-supported VITA YZ HT zirconium dioxide (Fig. 3). For a deep initial fluorescent effect, a wash firing was performed with EFFECT LINER 5 (orange) and EFFECT LINER 6 (green-yellow). Layering with VITA VM 9 was the foundation for reproducing the basic shade (Fig. 4). The VITA INTERNO materials then enabled intensification of the deeper individual shade nuances after the wash and dentine firings (Figs. 5 & 6). Int 04 (orange) and Int 11 (grey-brown) were used in the cervical and interdental areas; Int 05 (terracotta) was used in the centre. The inside areas were nuanced with Int 08 (blue), Int 05 (terracotta) and Int 07 (anthracite), and the incisal edges with Int 02 (sand). Cracks and brown spots were reproduced with Int 10 (brown), and white spots with Int 01 (white).

Finalisation of the restorations

After establishing the basic morphology with a stone and the details with a fine diamond-coated bur, the interior crack was recreated from the outside with a fissure bur to achieve a 3-D effect. The surface texture was kept as smooth as possible, in accordance with the patient’s age. After the glaze firing, only a goat hair brush and diamond polishing paste were used to slightly reduce the gloss effect. After trying out the full-ceramic crown, the patient was very satisfied with the result (Fig. 7), and a self-adhesive bonding agent was applied. The shade and form of the restoration integrated harmoniously with the other teeth (Fig. 8). The veneering ceramic, in combination with two stain firings, made it possible to achieve age-appropriate aesthetics (Fig. 9).

about

Carolin Wehning
is a dental technician in Bocholt in Germany.

Fig. 7: The patient was very satisfied with the final aesthetic result. Fig. 8: The shading and lighting of the restoration fitted in perfectly with the overall picture. Fig. 9: The final full-ceramic crown had an age-appropriate morphology, surface texture and shading.
New materials for a classic indication
Cementation of all-ceramic restorations using Variolink Esthetic

Drs Eduardo Mahn & Juan Pablo Sánchez, Chile

**Zinc phosphate cements** are seen as classic luting materials for the cementation of metal-ceramic crowns. Along with all-ceramic materials, glass ionomer cements (GICs) and resin-modified glass ionomer cements (RMGICs) were introduced. Generally, luting cements are expected to meet certain requirements: they should provide an optimum bond to the tooth structure and restorative material, must not be soluble in water, should be suitable for application in thin coatings and should offer long-term stability. This is in contrast to the properties of classic cements, which are water soluble and do not establish an adhesive bond to the enamel or dentine (zinc phosphate cements) or establish only a minimally adhesive bond and only to the dentine (GICs and RMGICs). Nonetheless, these cements show reasonable survival rates if used for the appropriate indication even if they have certain limitations.

**Problem 1: Opacity**

The opacity of the luting material is a critical issue for all-ceramic crowns, as well as ceramic inlays and onlays. Almost any colour can theoretically be reproduced with ceramics by exploiting their natural translucent properties. Using an opaque luting material appears to be counterproductive in achieving this. Further critical issues are the limitations involved in the anterior region and the location of the cement line in the visible area for inlays and onlays. For instance, if a tooth is restored with a veneer, the basic shade of the tooth is maintained; only the enamel is replaced, usually by using a translucent ceramic that covers the natural dentine. In such a case, it is essential to use a translucent luting material to achieve a favourable result.

**Problem 2: Adhesion**

The comparatively low bond strength of conventional cements is also problematic. Classic preparations around the tooth create a high degree of friction and retention. However, the retention is significantly reduced with partial crowns, veneers or onlays. It is therefore advisable to use a luting material that is capable of providing a strong adhesive bond. Both problems led to the widespread use of...
luting composite materials. Perhaps their only disadvantage is the removal of excess material. These luting materials are hard and solid and not water soluble, and they have a high adhesive strength, making removal of excess difficult. Early luting composites were equipped with a self-cure mechanism. Users had to wait a few minutes until the composite was almost fully set before they could remove the excess material. This period was risky because of the moisture in the mouth. Blood or saliva could come into contact with the non-polymerised composite and cause damage.

Dual-curing luting composites

These issues led to the rise of dual-curing composites for the cementation of all-ceramic crowns. Dual-curing luting composites are usually delivered in double-push syringes with a mixing tip. During extrusion, the base and catalyst are automatically mixed. The material can be applied directly. The main advantage is that the curing process can be accelerated with light and excess material can easily be removed. At the same time, the self-cure mechanism ensures a reliable cure, even with relatively thick or opaque ceramic layers. Nonetheless, there are some situations in which excess material cannot be removed all that easily because the setting reaction takes place too quickly or the material does not cure down to the depth of the composite layer. After one second of light curing, the surface is set and excess can be broken off, but the material is still paste-like at the interface to the crown or tooth. Excess can be polymerised en bloc and pulled off as a ring in one go with no uncured material left in contact with the tooth or crown. In addition, the luting composite does not contain amine, which is another advantage, since amine may be implicated in discoloration of the cement line over time.

One material, five shades

Variolink Esthetic (Ivoclar Vivadent) is based on the value shade concept. The shades are classified according to the effect to be achieved with the cement. Five shades are available: Light+, Light, Neutral, Warm and Warm+. In this way, the shade spectrum ranges from an opaque white tone (Light+) to an opaque yellow-brownish shade (Warm+). In between lie shades such as a coconut water white and a neutral tone (very translucent) and a warm tone (comparable to A3). In addition, the luting composite is available...
in an LC (light-curing) and a DC (dual-curing) version. The LC version is designed for relatively thin restorations, such as inlays, onlays and veneers. The DC version is suitable for more extensive and opaque restorations. The luting composite is used in conjunction with the light-curing single-component Tetric N-Bond Universal (Ivoclar Vivadent).

Clinical case

A 45-year-old male patient presented to the practice with a restoration on tooth #46. The tooth had been endodontically treated and temporised with a filling (Fig. 1). The temporary was removed, the tooth built up with Tetric N-Ceram Bulk Fill (Ivoclar Vivadent) and then prepared for the crown restoration (Fig. 2). An impression was taken with a one-step, two-phase impression technique using a putty and light-body silicone. After scanning the model, the crown was designed in the software suite (inLab, Dentsply Sirona) and milled from an IPS e.max CAD lithium disilicate block (Ivoclar Vivadent; Figs. 3a & b). After the crystallisation firing, the crown was stained and glazed (Fig. 4). The next step was to etch and silanate the ceramic crown with the new glass-ceramic primer Monobond Etch & Prime (Ivoclar Vivadent). This primer combines a ceramic etching and silanating component in a single material and therefore eliminates the need for the ceramic to undergo hydrofluoric acid etching (Fig. 5). After the etching and silanating step, the crown was rinsed with water and dried. The isolated enamel was then etched (Fig. 6). The adhesive (Tetric N-Bond Universal) was applied and dispersed with a strong stream of air. The dual-curing version of the Variolink Esthetic luting composite was used for seating owing to the thickness of the crown and the low translucency of the ceramic material (Fig. 7). The luting composite was applied into the crown. The restoration was then seated (Fig. 8) and light-cured from each side for two seconds. Excess composite was easy to remove owing to the Ivocerin photoinitiator (Ivoclar Vivadent), which provides a fast and thorough cure with a minimum amount of energy (Fig. 9). For final polymerisation, the restoration was light-cured from each quarter for 20 seconds (Fig. 10). Figures 11 and 12a & b show the oral situation after placement of the crown. Although the cement line was located above the gingival margin, it was not visible owing to the favourable tone and opacity of the luting composite. Figures 13a & b show radiographic control images of the restoration: the radiopaque build-up material and cement can easily be distinguished from the tooth structure. This aspect is particularly important in situations where excess cement cannot be seen with the naked eye.

Conclusion

The cementation methods used in conjunction with all-ceramic materials have changed for single-crown restorations. Variolink Esthetic is a protagonist of the latest generation of luting composites. Excellent bond strength values, coupled with user-friendly handling characteristics and highly aesthetic properties, make this material an asset in day-to-day dental restorative care.

contact

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Bioactivity in restorative dentistry: A user’s guide

Dr Fay Goldstep, Canada

Introduction

The word “bioactivity” is one of the latest buzzwords in the dentistry. It is highlighted as a feature in many restorative products with different and conflicting claims. This has stirred up confusion and controversy surrounding the concept. This article will attempt to provide clarity for the practising restorative dentist regarding the following: What is bioactivity? What are bioactive products? How can they be used to provide the best dental care?

The term “bioactive material” originated with Dr Larry Hench in 1969. He was looking for an improved graft material for bone reconstruction needed by injured returning soldiers of the Vietnam war. Hench was searching for a material that could form a living bond with tissues in the body. All the available materials at the time were rejected by the body. He developed bioglass (calcium silicophosphate glass), a completely synthetic material that chemically bonds to bone.1 Hench defined a bioactive material as “one that elicits a specific biological response at the interface of a material which results in the formation of a bond between the tissues and the material”.2

Today, there are many different definitions of bioactivity found in the dental literature, dependent on the research and on the researcher. The definition fits the research, whereas it should fit the concept. In order to achieve clarity of meaning, it is best to go with what can be most easily understood by clinicians and patients alike, the definition found in the dictionary: “bioactivity”, noun: any effect on, interaction with or response from living tissue.

Historically, dental materials were designed to have a “neutral” effect on the tooth.3 Many current dental materials are not neutral. They are “active”, not “passive”, participants in the restorative process. New materials are being developed to harness this potential behaviour. These are “bioactive” materials.

For simplification and clarity in discussing bioactive restorative materials, it is best to separate them according to their mechanism of action. There are three separate mechanisms that are demonstrated by bioactive restorative materials (Table 1 lists examples of bioactive restorative materials by their mechanism of action). A bioactive restorative material can display one or more of the following actions:

1. Remineralises and strengthens tooth structure through fluoride release and/or the release of other minerals;
2. forms an apatite-like material on its surface when immersed in body fluid or simulated body fluid over time;4
3. regenerates live tissue to promote vitality in the tooth.

Materials that remineralise

Dental caries is the cumulative result of consecutive cycles of demineralisation and remineralisation at the interface between biofilm and the tooth surface. Oral bacteria excrete acid after consuming sugar, leading to demineralisation. Hydroxyapatite crystals are dissolved from the subsurface. Remineralisation is the natural repair process for non-cavitated lesions. It relies on calcium and phosphate ions, assisted by fluoride, to rebuild a new surface on the existing crystal remnants in the subsurface.5

Under normal physiological conditions at a pH of 7, saliva is supersaturated with calcium and phosphate ions, making caries progress slow. As the pH is lowered, higher concentrations of calcium and phosphate are required to reach saturation with respect to hydroxyapatite.6 This is called the “critical pH”, the point where equilibrium exists and there is no mineral dissolution and no
mineral precipitation. The critical pH of hydroxyapatite is around 5.5 and that of fluorapatite is around 4.5. This varies with individual patients. Below critical pH, demineralisation occurs, while above critical pH, remineralisation occurs (Figs. 1 & 2).43

If fluoride is present in the plaque fluid, it will penetrate the enamel, along with the acids at the subsurface, adsorb to the apatite crystal surface and protect the crystals from dissolution.6 This coating makes the crystals similar to fluorapatite (critical pH of 4.5), ensuring that no demineralisation takes place until the pH reaches this point. Fluoride present in solution at low levels among the enamel crystals can markedly decrease demineralisation.7, 8

When the pH returns to 5.5 or above, the saliva, which is supersaturated with calcium and phosphate, forces minerals back into the tooth.8 Fluoride increases remineralisation by bringing calcium and phosphate ions together and is preferentially incorporated into the remineralised surface, which is now more acid-resistant.

The benefits of fluoride are maintained long term through the mechanism of fluoride reservoirs. Fluoride is retained intrarally after fluoride treatments, such as fluoridated toothpaste and fluoride varnish application, and is then released into the saliva over time.8, 9 Fluoride can remain on teeth, mucosa or dental plaque or within bioactive restorative materials. Fluoride retention is clinically beneficial, since it can be released during cariogenic challenges to decrease demineralisation and enhance remineralisation.3

When the enamel and dentine no longer have adequate structure to maintain their mineral framework, cavitation takes place and simple remineralisation is an insufficient treatment. Tooth preparation and restoration are now required.

Bioactive restorative materials replace dental hard tissue and help to remineralise the remaining dental structures. Glass ionomer cements and their derivatives, such as resin-modified glass ionomers, compomers and giomers, fall into this category.
Glass ionomer cements

Glass ionomer cements were developed in the early 1970s. They are particularly valuable for caries control in high caries risk patients and in areas where location or isolation create restorative challenges (Figs. 3a & b). Glass ionomers have a true chemical bond with dental tissue. They encourage remineralisation of the surrounding tooth structure and prevent bacterial microleakage through ion exchange adhesion with both enamel and dentine.11 A new, ion-enriched layer is created at the tooth–glass ionomer interface. This layer contains phosphate and calcium ions from the dental tissue, and calcium (or strontium), phosphate and aluminium from the glass ionomer cement.11 The remineralisation process creates a harder dentine surface (Fig. 4).12, 43 Restoration fracture is usually cohesive, leaving the ion exchange layer firmly attached to the cavity wall. The dentinal tubules are sealed and protected from bacterial penetration.13

In order to eliminate the physical property disadvantages of glass ionomers and harness their remineralising benefits, dental researchers have produced an assortment of glass ionomer derivatives: resin-modified glass ionomers, composites and giomers. Two product lines in this category are ACTIVA BioACTIVE-RESTORATIVE (Pulpdent; Fig. 5) and the Beautifil giomer family of restorative materials, including Beautifil II and Beautifil Flow Plus (SHOFU; Fig. 6). Studies have shown ACTIVA's remineralisation potential through fluoride release and recharge and calcium release.14, 15 Giomers are used in restorative dentistry as equivalent to composite resin, in all their applications.

Giomers

Giomers represent the hybridisation of glass ionomer and composite resin properties: the fluoride release and recharge of glass ionomers, and the aesthetics, physical properties and handling of composite resins.16 The giomer concept is based on PRG (Pre-Reacted Glass) technology: a glass core, surrounded by a glass ionomer phase enclosed within a polyacid matrix. Studies show that dentine remineralisation occurs at the preparation surface adjacent to the giomer.17

Giomers, through the creation of fluoride reservoirs, release and recharge fluoride efficiently, significantly better than do composites18 and composite resins, although not as well as glass ionomers.19 The clinical performance of giomers has been tested against those of hybrid resin composites. Giomers have been found to compare positively for all criteria.20

Materials that deposit hydroxyapatite

Some bioactive materials not only remineralise by adding minerals to tooth structure, but also create an apatite-like material on their surfaces when immersed in body fluid or simulated body fluid over time.4 There are...
two chemical classes of these bioactive restorative materials: calcium silicates and calcium aluminates.\textsuperscript{21, 22} These materials are non-resin-based. Both materials set with an acid–base reaction and produce an alkaline pH after setting. High pH levels (7.5 or higher) appear to stimulate more active and complete bioactivity.\textsuperscript{4}

Ceramir (Doxa Dental; Fig. 7) is a calcium aluminate material developed for cementation. An \textit{in vitro} study found that this apatite-forming bioactive cement can occlude artificial marginal gaps. This is beneficial clinically at the margin of the prepared tooth and cemented restoration. It suggests that bioactive dental materials may significantly improve clinical outcomes and longevity of dental restorations.\textsuperscript{23}

Calcium silicates have also been shown to deposit hydroxyapatite.\textsuperscript{23} Even more importantly, they can stimulate the regeneration of live tissue: dentine, pulp, blood vessels and bone.\textsuperscript{24–26}

Materials that can regenerate live tissue

Some bioactive materials not only remineralise and form hydroxyapatite, but also regenerate live tissue. This is crucial in many restorative and pulp-related treatments. One major example is vital pulp therapy. The goal of vital pulp therapy (direct pulp capping and pulpotomy) is to treat reversible pulpal injury arising from trauma, caries or restorative dentistry. These injuries destroy the normal tissue architecture at the pulp–dentine interface, but can be healed if the wound is properly protected.\textsuperscript{21}

Treatment must maintain pulp vitality and function and restore dentine continually below the injury through hard-tissue bridge formation.\textsuperscript{20} Optimal quality of this hard-tissue bridge is essential to the long-term success of vital pulp therapy.\textsuperscript{29, 30} There is a pulp tissue-specific response to the capping material, and this determines the quality of the dentine bridge.\textsuperscript{29}

Calcium hydroxide products have been used in vital pulp therapy for many years. The ability of calcium hydroxide to promote dentine bridge formation and enhance wound healing is well established.\textsuperscript{31} However, calcium hydroxide has inadequate physical properties and produces poorly formed dentinal bridges containing tunnels.\textsuperscript{32} This has directed research to seek out new materials for this therapy.

The first of these materials created for practical clinical use was mineral trioxide aggregate (MTA).\textsuperscript{23} MTA was originally developed as a root end filling material for apicectomy procedures and to repair root perforations.\textsuperscript{24} Indications for its use have expanded broadly within restorative dentistry and paediatric dentistry.\textsuperscript{27}

MTA is a calcium silicate-based material (derived from Portland cement) with high sealing ability and excellent biocompatibility. MTA-based materials stimulate faster formation of dentinal bridges that are of better quality than those of calcium hydroxide.\textsuperscript{25, 30} Since the mid-1990s, MTA has been recognised as the standard in conservative pulp vitality treatment.\textsuperscript{20} MTA-based materials have limitations however:

- Long setting time;\textsuperscript{30}
- weak mechanical properties;\textsuperscript{38}
- difficult handling;\textsuperscript{38}
- may produce tooth discolouration;\textsuperscript{39}
- may contain heavy metals.\textsuperscript{40}

Much research has followed to build on the advantages of MTA while eliminating most of the disadvantages. One such material is Biodentine (Septodont; Fig. 8). It was formulated by improving the physical and handling properties of MTA-based endodontic repair cement technology and creating a dentine replacement material with significant reparative qualities.

Biodentine can be used as a complete dentine replacement material to treat damaged dentine in both the crown and the root with clinical indications that exceed those of MTA and other related Portland cement calcium silicate products.\textsuperscript{21} Biodentine can be used as a:

- cavity base/liner in deep carious lesions;
- pulp capping agent in vital pulp therapy (both direct pulp capping and pulpotomy);
- root repair material for perforations, resorptions, apicification and root end filling material in endodontic surgery; and
– restorative material to replace missing or defective dentine.

It cannot be used to replace enamel.

The advantages of Biodentine over MTA and modified MTA materials include:

– Ease of handling;
– high viscosity;
– shorter setting time (12 minutes);
– better physical properties;41
– composition containing raw materials with known degree of purity;42 and
– good colour stability, so there is no discolouration.43

Biodentine is a tricalcium silicate-based material. Its mechanical properties compare to those of dentine, and it can be used as a dentine substitute in both the crown and the root.44–46 It stimulates deposition of hydroxyapatite when exposed to tissue fluids.47 It is non-toxic as tested on human pulp cells.48 Studies have shown complete dentinal bridge formation after six weeks in human teeth.49

Biodentine provides a hermetic seal that protects the dental pulp by preventing bacterial infiltration. This creates a protected environment where healing can take place. The seal is created through micromechanical retention by infiltrating the dentine tubules and by stimulating odontoblasts to deposit dentine.25

It is the calcium-releasing ability of pulp capping materials that induces pulp tissue regeneration. Tricalcium silicate-based materials like Biodentine produce calcium hydroxide as a product of hydration.50

The calcium silicate setting reaction is as follows:

$$2(3CaO.5SiO_2) + 3H_2O \rightarrow 3CaO.2SiO_2.3H_2O + 3Ca(OH)_2$$

calcium trisilicate
hydrated calcium silicate gel

calcium hydroxide

Calcium silicate in the powder interacts with water, leading to the setting and hardening of the cement. This produces hydrated calcium silicate gel and calcium hydroxide. Calcium hydroxide can now stimulate pulp regeneration within a gel-like material that is strong and not porous; this harnesses the regenerative powers of calcium hydroxide without its physical disadvantages.

Biodentine in vital pulp therapy, through the action of calcium hydroxide in this enhanced physical state, boosts the deposition of reparatory dentine by odontoblasts. This creates a dense dentine barrier,51, 52 as well as heals damaged pulp fibroblasts.53 Clinical results have confirmed Biodentine’s ability to preserve pulp vitality even in very difficult cases. It has the potential to heal pulps, avoiding what may have been inevitable endodontic involvement in the past.

Resin-modified calcium silicates

Studies have shown that the presence of a resin matrix modifies the setting mechanism and calcium leaching of calcium silicates.54 A partial pulpotomy clinical study compared TheraCal (BISCO), a light-cured, resin-modified calcium silicate base/liner designed for direct and indirect pulp capping, with non-resin-containing materials Biodentine and ProRoot MTA (Dentsply Sirona). The results showed that Biodentine achieved complete dentinal bridge formation in all teeth. The rates for bridge formation were 56 % for ProRoot MTA and 11 % for TheraCal.55 Normal pulp organisation was seen in 66.6 % of the teeth in the Biodentine group, 33.3 % of the ProRoot MTA group and 11.1 % of the TheraCal group. The study concluded that the non-resin-based partial pulpotomy materials perform better than the resin-based materials and present potential for the best clinical outcomes.55

Another recent study compared Biodentine with TheraCal with respect to how they each affect inflammation and regeneration of the pulp in a direct pulp capping in vitro model. TheraCal was shown to increase inflammatory cells and decrease the regenerative processes of the pulp, whereas Biodentine did not increase inflammation and supported the regenerative processes of the pulp.56

These two studies seem to suggest caution in using resin-based materials for vital pulp therapy. Biodentine has good biocompatibility and bioactivity for use in vital pulp therapy.
Calcium silicates as endodontic sealers

The ability to deposit hydroxyapatite and regenerate live tissue has brought calcium silicate technology into the scope of endodontic sealers. After obturation, there is generally contact between the obturating materials and the periapical tissue. The success of treatment greatly depends on the integrity of the obturated seal to prevent recurrent infection of the periapical space.

The introduction of bioactive endodontic sealers has changed the concept of obturated seal from hermetic sealing with inert materials to biological bonding with bioactivity. The sealer becomes a filler, not only a sealer.

Calcium silicates are well suited to endodontic obturation owing to the following properties:

- High pH (antibacterial);
- hydrophilic (use moisture present in dentinal tubules to initiate set);
- biocompatible;
- do not shrink or resorb;
- excellent seal (bond chemically and mechanically to dentine); and
- ease of use (can be used with many methods of condensation).

Furthermore, they are bioactive:

- Remineralise hard tissue;
- deposit hydroxyapatite to improve the seal over time;
- regenerate and heal surrounding periapical tissue.

BioRoot (Septodont; Fig. 9) has been developed to incorporate these bioactive traits. Research has shown:

- **Hydroxyapatite formation upon setting reaction**: Bio-ceramic sealers bond to dentine through the process of alkaline etching. This is due to the alkalinity of the sealer. A mineral infiltration zone develops between the dentine and the sealer.
- **Tissue healing**: A study that compared the effects of BioRoot RCS on human periodontal ligament cells with the standard zinc oxide eugenol-based root canal sealer, Pulp Canal Sealer (Kerr Dental), showed BioRoot to have fewer toxic effects on periodontal ligament cells and that it induced greater secretion of angiogenic and osteogenic growth factors. These properties are essential in periapical tissue regeneration.
- BioRoot also showed excellent biocompatibility when compared with many other contemporary endodontic sealers.

**Conclusion**

With a bit of simplicity and focus on the essentials of bioactivity in dentistry, it becomes clear that bioactivity is now an essential part of the practice of clinical dentistry. Dentists can now harness the potential to remineralise and generate tooth material and heal biological structures for their ultimate objective: attaining the best possible clinical outcomes for their patients.

**Fig. 9:** BioRoot is a bioactive endodontic sealer that remineralises, deposits hydroxyapatite and regenerates live tissue.

**Editorial note:** A list of references is available from the publisher.

**contact**

**Dr Fay Goldstep** has been an ADA (American Dental Association) Seminar Series Speaker and lectured at the ADA, Yankee, American Academy of Cosmetic Dentistry, Academy of General Dentistry and Big Apple dental conferences. She has lectured nationally and internationally on proactive/minimal intervention dentistry, soft-tissue lasers, electronic caries detection, healing dentistry and innovations in hygiene. Dr Goldstep has served on the teaching faculties of the postgraduate programmes in aesthetic dentistry at the State University of New York at Buffalo, universities of Florida and Minnesota, and University of Missouri–Kansas City in the US. She sits on the editorial boards of the *Oral Health Journal* (healing/preventative dentistry), *Dental Tribune U.S. Edition* and *Dental Asia*. She is a fellow of the American College of Dentists, International Academy for Dental-Facial Esthetics and American Society of Dental Aesthetics. Dr Goldstep has been a contributing author to four textbooks and has published more than 60 articles. She has been listed as one of the leaders in continuing education by *Dentistry Today* since 2002. Dr Goldstep is a consultant to a number of dental companies and maintains a private practice in Toronto in Canada. She can be contacted at epdot@rogers.com.
The digital world is creating numerous opportunities for dental practices. To the practitioner, these may seem countless and it may not be easy to keep pace with relevant developments. The 2019 International Dental Show (IDS), which is to be held from 12 to 16 March in Cologne in Germany, will present the state-of-the-art technology and help clinicians determine the most suitable solutions for their practices and focus of work following the motto “It depends on which innovation brings me and my practice forwards here and now.”

The impetus for digital processes is often triggered as a consequence of today’s patient. A typical situation: the patient needs a crown replaced; however, his time constraints demand same-day treatment. One solution could be a chairside system and another a particularly fast digital workflow that includes the practice and the laboratory. Considerations regarding the ideal restorative materials also play a role. IDS will present the entire palette of options to the visitor and thus also lays the basis for well-founded investment decisions.

Whereas in the above-mentioned case, the priority was above all speed, digital technologies assist with both complex and difficult treatments. For example, in the field of implantology, a patient requires a fixed prosthesis for his edentulous mandible. Based on radiographs and model scan data, the dentist–dental technician team plans the treatment together in the scope of backward planning from the final prosthesis to the positions of the individual implants. The digital availability of the data facilitates this process and if necessary also enables a further professional to be involved—even at short notice.

There are various ways of implementing the planned treatment, including many options that involve digital support. For example, for a safe surgical treatment, drilling templates can be ordered from the dental laboratory or from an industry partner that provides the service. External support is also available for the virtual design and production, so that the individual work steps can be more flexibly divided up among the team (surgeon, prosthodontist, dental technician) today than ever before. In this way, the practice aims to achieve quality assurance or, indeed, an improvement in the quality, while at the same time possibly saving time and money. Experts predict a pace of progress that will mean that by IDS 2019 or IDS 2021 at the latest more digital implant treatments will take place than analogue treatment using standard products.

“The current trends for the digital technologies for the practice, as well as extensive workflows for surgeons, prosthodontists and dental technicians, will be presented in a unique form at IDS,” said Mark Stephen Pace, Chairman of the Board of the Association of the German Dental Industry. “The opportunities of digital dentistry have now arrived in all disciplines—from implantology and prosthetics, through to endodontics and orthodontics. As such, it is certainly worthwhile for representatives from all specialised areas to experience the current innovations at IDS in a diversity that can be found in no other place.”
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www.hkideas.org

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www.world-dental-congress.org

**ESCD Annual Meeting**
20–22 September 2018
Lisbon, Portugal
www.soulofeffectiveness.eu

**Dental-Expo**
24–27 September 2018
Moscow, Russia
www.dental-expo.com

**IFEA 11th World Endodontic Congress 2018**
4–7 October 2018
Seoul, Korea
www.ifea2018korea.com

**DenTech China – Exhibition & Symposium**
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Shanghai, China
http://www.dentech.com.cn

**JADR Annual Meeting**
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http://jadr66.umin.jp

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