TECHNO-POLYMERS – 21ST CENTURY SUPPORT STRUCTURES

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For decades, the dental industry defaulted to alloys for support structure materials. In the 20th century, most technological advancements were made around the lost wax technique with a focus on wax and alloy development[1]. This alloy-based technology was also almost exclusively where most of the product evolution in the dental industry was taking place. Prior to 2010, a shift towards finding metal-free solutions started developing[2]. The start was rocky at best, but this new direction started gathering steam especially in the crown and bridge arena. Unfortunately, the development of support structure materials for removable applications lagged behind their counterparts in the fixed prosthetic arena for many years. More recently material manufacturers have shifted their focus to the removable industry with an emphasis on digitally compatible options.

With a shortage of skilled labor[3] becoming a real concern in almost every business, the importance of digital design and production to reduce the need for hand processes has become paramount to survival in the dental industry. For many years, the focus of alloy manufacturers was not only on biocompatibility, but also on economics. Those factors are still of utmost importance today, but new polymer materials are now also adding additional benefits like material compatibility and chemical bonding between different components that make up the final prosthesis. Because of better flexural compatibility, these materials inherently also offer an improved long-term material interaction between the acrylic overlay and support structure components.

Ultimately, the combination of chemical bonding, material and flexural compatibility reduces material fatigue and the chance of debonding. This results in a better long term survival rate of the prosthesis without compromising strength.

Plastic - Celluloid to Techno-Polymers

To truly understand the advantages of a material, and to identify its potential weaknesses, it is helpful to understand its history and development. Modern-day techno-polymers used in dental application often includes

Fig. 1

Fig. 2

a fibrous component to support the polymer. Throughout the evolution of plastics[4], there has always been a strong correlation between these synthetic fibers and polymers.

The first semi-synthetic plastic material developed was polystyrene. This material was derived by distillation of a vegetable resin in 1839. Bakelite was the first real synthetic thermosetting resin and was patented in 1910. This material quickly became the most widely used plastic material in the world. In the 1920's, universities began to systematically study the properties of natural and synthetic polymers. The late 1930's saw the birth of the first synthetic fibers. In 1935, polyamide was synthesized and found immediate real-world applications under the well recognized name, nylon.

The defining moment in the evolution of plastic products came in the 1960's with the development of polypropylene. This product quickly became a symbol of trendiness and modernism. Soon after, polyethylene was developed, and it was widely seen as one of the most popular thermoplastic polymers because of its great versatility and cost-effective characteristics.

Over the last few years, so-called techno-polymers have become increasingly popular and used in more and more sophisticated applications. Products like polymethylpentene, due to its absolute non-toxicity and resistance to chemical agents, is used to produce articles for use in clinical laboratories.

Today, modern day variants of polymers are used for specialized applications like astronaut helmets, contact lenses, bulletproof vests, dental prosthetic support structures (FIG.1) and even printed digital dentures (FIG.2).

Techno-Polymer Comparison Chart

Properties	Human	Bioloren Trilor	Trinia	CM Pekkton	Juvora PEEK	Zicornia + Ittrio
Tensile Strength	150 MPa	380 MPa	169 MPa	115 MPa	100 MPa	348 MPa
Flexural Strength	209.93 MPa	540 MPa	393 MPa	200 MPa	170 MPa	1200 MPa
Tensile elongation	2%	2%	2.7%	4,4%	20%	
Flexural modulus	8.51 GPa	26 GPa	18.8 GPa	5.0 GPa	4.0 GPa	210 GPa
Tensile modulus	20.7 GPa	26 GPa	18.8 GPa	5.1 GPa	3,7 GPa	210 GPa
Compressive Strength	90-209 MPa	530 MPa	347 MPa	246 MPa	118 MPa	2000 MPa

HarvestDental

www.harvestdental.com

Fig. 3

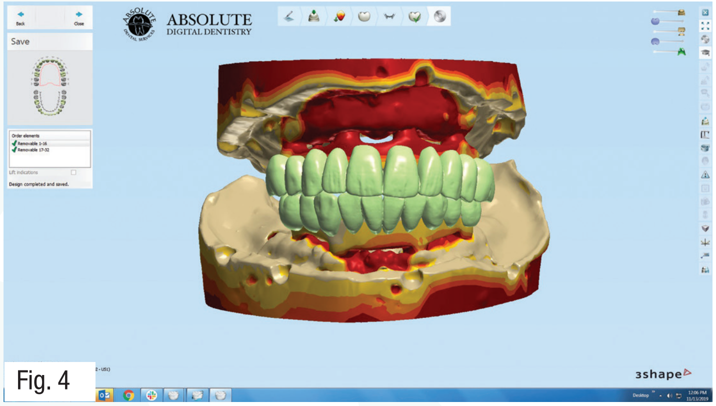

Fig. 4


Fig. 5


Fig. 6

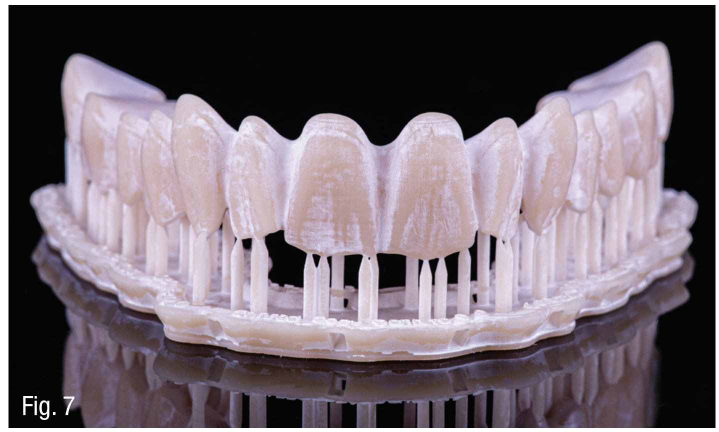
Fig. 7

The difference between plastic and techno-polymer is; unlike plastic used in everyday application, techno-polymer is defined as any plastic material used to fabricate something traditionally made of metal[5].

Support-Structure Options

Currently, there are four main competitors in the dental techno-polymer support-structure market in the US: Bioloren® Trilor®, (Harvest Dental, www.harvestdental.com / PREAT, www.preat.com), Juvora™ PEEK-OPTIMA®, (Invibio, www.invibio.com), CM Pekkton®, (anaxDENT, www.anaxdent.com), Trinia®, (Trinia, www.trinia.com / SHOFU® Dental, www.shofu.com).

Even though all the above materials are indicated, and FDA cleared for dental sub-structure fabrication, they vary in areas like polymer and fiber make-up. This ultimately influences the materials' flexural, tensile, and compressive strength (FIG.3). It is therefore important to carefully choose the type of sub-structure material to best match the required prosthetic application. Furthermore, having multiple options allows the technician to match the sub-structure with the overlay material of choice.

The importance of processing a well-supported prosthesis, designed, and manufactured in a digital workflow, has been proven to influence both the longevity of the prosthesis and predictability of the clinical workflow.

Having the ability to digitally design the case, convert the design to a prototype for patient acceptance, and then simply matching the approved data into the final prosthesis, is crucial for a predictable outcome.

Historically, outsourcing a support structure allowed human design interpretation to potentially influence the case. This outsourcing ultimately removed the sub-structure support design control from the technician responsible for the final prosthesis.

Even though these options are inherently different, they do have one big advantage in common: they are all available in puck form for reductive processing in a milling unit. This allows the laboratory to digitally control the support design, based on the patient approved tooth positions. Having the ability to fabricate the entire prosthesis in an in-house environment also speeds up the process and greatly reduces cost.

Fig. 8

Fig. 9

Many implant-supported hybrid failures have been attributed[6] to two main factors: flexural differences between old-school titanium substructures and acrylic overlay materials, as well as the lack of chemical bonding between the components. Modern-day techno-polymers solve both these potential issues. However, it is important for the technician to personally test the chemical bond strength between specific materials to find the best possible solution.

TECHNO-POLYMER CHARACTERISTICS

The latest generations of techno-polymers can be used in lieu of titanium frames with great confidence. They have been surprisingly well documented under the different brand names and boast an impressive track record over many years of intra-oral use.

When considering a replacement support-structure material, it is important to consider two crucial material attributes: flexural and tensile strength[7]. Flexural strength (also known as bend strength) is defined as the stress (MPa) in a material before it yields in a three-point bending test. Tensile strength[8], less important in dental applications, is defined as the maximum stress that a material can withstand while being stretched or pulled before breaking.

Most techno-polymers for dental application exhibit a flexural strength of between 160MPa and 540MPa. This attribute is crucial when matching the flex of natural bone (205MPa) to that of a techno-polymer support-structure.

Studies[9] performed by the MALO CLINIC on PEEK OPTIMA® found the material to mimic the behavior of

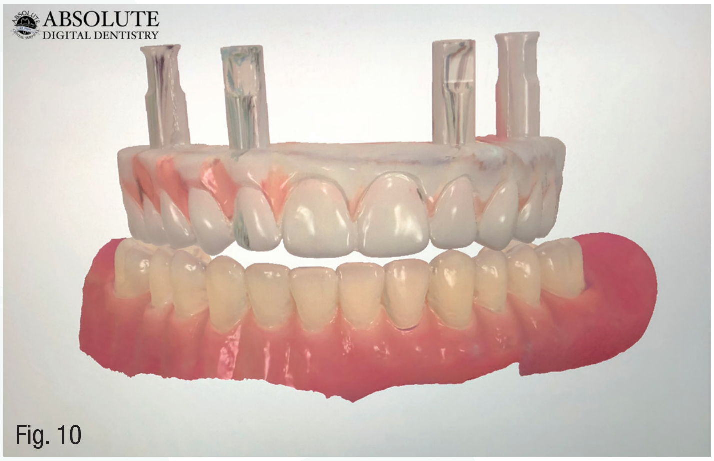

Fig. 10

Fig. 11

Fig. 12

the natural periodontal ligament by providing a cushioning and shock-absorbing effect in the mouth, even under extreme force. This study also showed an almost perfect implant survival rate (at 3 years) when All-on-four® (Nobel Biocare®, www.nobelbiocare.com) cases were restored with this techno-polymer as a sub-structure support.

A TriLor® / Crystal Ultra® (FIG.3) combination strength and wear study[10], performed by the University of Alabama at Birmingham, showed the Crystal Ultra® tooth-overlay material wear at a volumetric rate of 0.061mm^3 compared to Phonares® nano hybrid composite denture teeth (Ivoclar Vivadent, www.ivoclarvivadent.com) at a wear rate of 0.271mm^3. The TriLor® fracture test displayed an average initial fracture at 1626N and ultimate fracture at 1759N. Compared to average biting forces on a molar of 60N, and a maximum clenching force of between 600N and 900N, this material combination proved to be a highly functional solution.

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TOOTH OVERLAY OPTIONS

The use of individual denture teeth in implant supported applications, where occlusal forces are different from tissue-supported dentures, is also a potential weakness. Using prefabricated carded teeth negates any potential digital workflows and requires arduous hand processes that cannot be digitally archived. Utilizing digital processing (FIG.4), allowed by techno-polymer sub-structures, brings with it the ability to mill (FIG.5) or print the final tooth overlay in lieu of using traditional denture teeth.

Different tooth overlay materials can be used depending on the application. There are currently multiple millable materials available that work exceptionally well for this type of prosthesis: Crystal-Ultra®, (Digital Dental, www.crystalultra.com), Temp-Esthetic™, (Harvest Dental, www.harvestdental.com), Ivotion Dent®, (Ivoclar Vivadent, www.ivoclarvivadent.com).

The industry is also starting to see the development of glass infiltrated photo polymer resins for tooth overlay printing: BEGO® Varseo, (BEGO, www.bego.com) and Formlabs® Permanent Crown, (Formlabs, www.formlabs.com). Even though the printable tooth overlay materials (FIG.6) development is still in its infancy, the promise of being able to print long-term tooth structures is the way of the future. Printing is more accurate and requires far less hand processing (FIG.7) compared to a milled counterpart (FIG.8). Therefore, this technology shows large promise for future application.

DIGITAL CASE PROTOCOL

When processing a hybrid, using a techno-polymer substructure with custom PMMA or nano-ceramic tooth overlay, the clinical process is simplified, and results are more predictable. Ultimately, the main reason for processing in a digital workflow is an adjustment free, predictable final delivery. By incorporating a prototype (FIG.9) into this workflow, the patient and clinician can "test drive" the digital design before proceeding to final delivery of the prosthesis.

Digital Hybrid Workflow

First appointment – Remove the transitional (conversion) hybrid. Place DME scan-flags and digitize the hybrid with an IO scanner. Replace the hybrid and scan the bite and opposing. Send the data (FIG.10) to the lab for PhaseII hybrid jig fabrication. Contact www.AbsoluteDentalLab.com for more detailed information on this process.

Lab Process – Create a prosthetic PhaseII hybrid for impression and bite verification.

Second appointment – Place the PhaseII hybrid, lute between sections, adjust bite, and flow PVS material between the tissue and the device. Take smile pictures and make diagnostic notes for any required changes. This device effectively indexes a verified impression, diagnostic tooth try-in, bite check and refreshed tissue level impression.

Lab Process – The lab will digitally design the PMMA prototype with the requested diagnostic adjustments and return the device for final try-in. It is essential to try this device in and establish patient acceptance and sign-off. If the patient has any concerns, the PMMA device can be worn as temporary, adjusted, or added to by using composite until patient sign off can be achieved. It is important to know that the approved transitional hybrid will become the final data file and this will be model matched and copy-milled precisely into the final prosthesis.

Lab Process – Import the PhaseII data files into the design software, make requested diagnostic changes and mill a PMMA transitional prototype.

Third appointment – Delivery of the hybrid prototype (FIG.11) and patient approval.

Lab Process – Import the approved prototype data into the design software and copy-mill the final hybrid.


Fig. 13


Fig. 14

Fourth appointment – Delivery of the final hybrid. In addition to the final hybrid, the prototype transitional is also delivered to the patient. This device is an exact copy of the final and will serve as an emergency prosthesis in case of failure.

Techno-Polymer Applications

This new generation of support-structure (FIG.12) materials can be used in a multitude of applications where the default used to be an alloy structure. Techno-polymers are indicated for partial frameworks, denture, and hybrid support structures and even for implant abutments and screws.

Nano-ceramics, in combination with a techno-polymer substructure, is an ideal solution for Locator® (ZEST® Dental, www.zest.com) supported dentures and is also a superior solution for the ATLANTIS™ Conus friction fit denture concept. (Dentsply Sirona®, www.dentsplysirona.com) (FIG13).

This material combination addresses the problem of denture tooth wear and debonding in implant supported cases where heavy occlusal forces are responsible for reducing the longevity of these prosthetic devices.

Advancements in digital workflows, combined with innovative products, benefit the patient with more predictable deliveries. Ultimately, these deliveries require less clinical appointments to complete and increase the longevity, esthetics, and function of the final prosthesis (FIG.14).

The dental landscape has already seen exponential technological advancements.

This is only the tip of an immense iceberg! In these exciting and sometimes uncertain times, understanding and embracing technology will define success...and ultimately survival in the 21st century! Sd

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