New Dental Implant Terminology for Exposing and Mitigating the Root Causes of Installation-Related Treatment Complications

Emil L.A. Svoboda PhD, DDS, February 7, 2021

Abstract: *As knowledge about dental implant treatment increases, there is a compelling need to add new words and phrases to the dental glossary to support easier and more precise communication, and to open new frontiers for dental research. The intent of this publication is to define new terminology that exposes the root causes of prosthesis installation related treatment complications, and to show how their negative effects can be mitigated.*

Existing Terms *are discussed to provide context for New Concepts and Terminology: Standard of Care and New Standard of Care; Optimized Fit of connecting implant parts; Government Regulated Fit of implant parts sold in Canada and the USA; Optimized Fit of implant parts; Clinically Acceptable Fit of implant parts; Root Causes of Peri-implant Disease; Screw Retained Prosthesis; Complications inherent to the Screw-in System of Prosthesis Installation; Prosthesis Retrievability; Retrievability Features; Complications Related to the current Cement-in System of Prosthesis Installation.*

New Concepts and Related New Terminology*: The Root Causes of misfit implant parts, poor prosthesis margins, and subgingival cement are Prosthesis Dimensional Error and the Tissue Effects. The Tissue Effects include Resistance to Displacement and the Gingival Effects; Screw-in System of Prosthesis Installation; Cement-in System of Prosthesis Installation; Trans-Tissue Portal; Reverse Margin System of Prosthesis Installation; Upgrading the Current Screw-in and Cement-in Prosthesis Installation Systems; The Svoboda Way of Prosthesis Installation; Installing the All-On-X Prosthesis the Svoboda Way.*

It is the author's hope, that understanding the root causes of procedure-related complications will encourage dentists to consider and integrate new solutions into their treatment protocols and guide future improvements in the predictability of dental treatment. Extrapolated from the study of Wilson 2009, preventing residual subgingival cement could reduce implant treatment complications by 60%. This document is intended to help usher in a New Standard of Dental Care.

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As knowledge about dental implant treatment increases, there is a compelling need to create new words and phrases to support easier and more precise communication among dentists and those interested in dentistry. While some of this new terminology is best defined and illustrated by examples from the field of dental implantology, it can also be used for discussing a range of topics relevant to dentistry in general.

The intent of this publication is to clearly define new terminology that exposes the root causes of procedure-related treatment complications, and to show how they have been mitigated by the solutions proposed by the author. It is also the author's hope that understanding the root causes of complications will help guide future improvements to the predictability of implant-based treatment.

Complications caused by current installation protocols are mainly mechanical in nature. The most serious consequences of these mechanical complications are biological. It is only recently, that the existing technology has entered the microscopic arena and given dentists better tools with which to prevent microscopic problems microscopically. The macroscopic tools for assessment of fit; direct vision, pigtail explorers, x-ray images, and tactile feel of prosthesis stability in the mouth are less than adequate for assessing microscopic fit. This has led to non-optimal treatment for patients and a troubling prevalence of peri-implant disease for the Profession.

Standard of Care: Standard of Care is a dynamic concept that changes as improvements to treatment become available. What was best yesterday, may no longer be best today. For example, it may be difficult for a dentist to successfully argue that the misfit connection of implant parts would suffice if optimal connection was possible. Optimized connections would thus become a realistic expectation of patients and the basis of a **New Standard of Care**.

Optimized Fit of Connecting Implant Parts: An optimized fit is the best fit achievable between implant parts. This may be accomplished, when parts are connected according to manufacturers' instructions and would be affected by properties of the mating manufactured parts. According to current technology, implant parts made from titanium alloy can be produced at a tolerance for error of ±5 microns. (1) When put together in an optimized fashion, one would expect the mating parts to be most stable under function and most resistant to penetration by oral pathogens.

The **Governments of Canada and the USA** believe stability of connecting implant parts is important. Thus, Health Canada and FDA regulations have imposed standards on the stability of connected implant parts. The implant industry must meet or exceed these standards to be granted permission to sell their parts in Canada or the USA.

When mating implant parts are submitted for testing, they are accompanied by instructions for their connection process. The manufactured parts are thus fastened together according to those instructions and then subjected to the testing processes. For example, one abutment would be attached to one implant by means of the included abutment fastening screw. The fastening screw would be torqued according to factory specifications before the implant-abutment is loaded into the testing machine.

It is assumed that these parts would be connected optimally for this in vitro test, because those submitting the parts for testing want to obtain permission to sell those parts to the dental community. Please note, this is an "in vitro" or laboratory test that intends to simulate stresses that these connected parts would be expected to withstand in the mouth of a patient over time. (Figure 1)

Figure 1: Machine made precision parts used to connect a prosthesis to implants installed in the jawbone of patients.

Optimized Fit of Implant Parts in the Mouth: In the mouth, the conditions under which these implant parts are connected can be much more complex. Prosthesis installation is usually carried out by dentists with varying levels of experience, who need to contend with patient management issues, various oral tissues, and obstructions to monitoring the process by direct vision. In addition, there can be multiple implants placed in the jaw at various angles to be restored with prosthetics of various sizes made by various processes with various inherent inaccuracies. So, the dentist must contend with the reality of different paths of insertion determined by implants and other dental units already in the mouth, under challenging conditions. If installing a prosthesis with optimally fitting parts sounds almost impossible, there is plenty of literature to confirm this. "Achieving the passive fit of a prosthesis in the mouth is not possible." (2)

There is even some literature that says misfit parts do not matter, because the researchers have not found a significant difference in complication rates experienced by patients who had their prosthetics installed with different degrees of misfit. One reviewer hastened to add, we did not find any differences in complication rates, but "We should aim to make parts fit as well as possible". (3) It is difficult to argue that misfit implant parts are somewhat good for a patient when the patient experiences mechanical complications and/or related biological complications like peri-implant disease. The prevalence of peri-implant disease is troubling.

It is well known in the scientific community that the interpretation of negative results is subjective at best. (4) Notably, not being able to discriminate a difference is not proof that a difference does not exist. Indeed, the reviewer's results could mean that current installation systems already expose the patient to so many risk factors for complications, that incremental misfits do not result in enough of a difference to be discerned by the experimental system in use.

The above interpretation is plausible as the rate of peri-implant disease observed is 45% of dental implants or 65% of patients, as many patients have more than one implant having. (5,6) Patients with 4 or more implants retaining a prosthesis were found to have 15 times the incidence of peri-implantitis than those with 3 or less implant retainers. (7) This finding follows the logical progression of "the greater the number of implants and the more expansive the prosthesis, the larger the expected misfits and the higher the rate of disease". Other variables may also be involved. Poor access to care under larger prostheses may allow for the buildup of plaque in the peri-implant environment and thus cause more peri-implant disease. Plaque is a known risk factor for peri-implant disease.

The implant treatment complication rate is still too high for dentists to feel comfortable about subjecting their patients to known risk factors for peri-implant disease when it is possible to reduce or eliminate them. If it were possible to consistently optimize the fit of parts in the mouth, would that not establish a New Standard of Care?

Dr. Svoboda has published a "proof of concept" article to demonstrate how that can be achieved for All-On-X prosthetics. By application of those concepts, **it is now possible for dentists to consistently optimize the fit of implant parts "in the mouth" under many common clinical conditions**. (8) This system of prosthesis installation is an example of a New Standard of Care.

When the conditions in the mouth of a patient make the optimization of the fit of implant parts or the prosthesis unlikely, it may be prudent for the clinician to discuss this problem with the patient before treatment begins. Knowingly exposing an unaware patient to risk factors for complications will likely increase the risk of extra-costs and early treatment complications. This is best discussed as part of the patient's informed consent process. (9)

It is not uncommon for implant vendors to advertise features of their manufactured parts that focus on the precision and stability of their parts when assembled optimally in vitro. None of these companies seem to be able to provide dentists with instructions that would allow them to assemble their parts optimally "in the mouth". However, they do give instruction, directly or indirectly through "Key Opinion Leaders" that might allow dentists to install prosthetics with a "Clinically Acceptable Fit".

Clinically Acceptable Fit: This is an expression used to describe the fit of parts in the mouth, where the parts appear to be stable when challenged by finger pressure or where gaps between components cannot be discerned using direct vision, instrumentation or conventional dental x-ray images. (10) However, the inability to detect the non-optimal fit of parts using current clinical armamentarium does not qualify connections as having been connected optimally. Nor does the term propose that the quality of fit of connected parts would fall within Health Canada or FDA approval criteria.

Non-optimized joints would be expected to be less stable under function and less able to exclude oral pathogens from between connected parts and from the internal spaces of the implant and abutment. This problem alone could subject the peri-implant tissues to a moving joint capable of pumping billions of oral pathogens from inside the implant-abutment spaces into the peri-implant environment. Peri-implant disease is a microscopic event with potentially dire consequences for the patient. Loose and broken screws can be an overt sign that the fit of parts has not been optimized, and peri-implant disease can be another.

There are several procedures, including the use of **intra-oral impression jigs as part of the master model technique**, that are designed to reduce the size of misfit of joints in the mouth. They may improve the fit of parts, but likely do not optimize the fit of parts. I would suggest these techniques may become somewhat irrelevant, (11) when dentists become aware of an installation system that can efficiently and consistently optimize the fit of parts in the mouth. (8) To do that, it is necessary to identify the root causes of misfit parts.

Root Cause: This is the fundamental reason for the occurrence of a problem or condition. (Collins Online Dictionary) Identifying and mitigating the root cause(s) of a problem, is basic to preventing those related problems and improving the chances of achieving better outcomes.

Root Cause of Peri-implant Disease: This disease is largely a result of oral pathogens that interact with the tissues adjacent to dental implants. (12) There are many factors that can affect the clinical expression of this disease process. (Figure 2) The size of the microbial inoculum, the virulence of the microbes within that inoculum, and the ability of the host immune system to defend itself against that inoculum. The interaction of these three factors can all affect the initiation and progression of peri-implant disease. For example, some oral pathogens may be highly virulent and thus be able to overcome the host's resistance in small numbers. Some less virulent microbes may occur in large numbers and thus cause their negative effects on the host tissues. Some immunocompromised hosts may find it difficult to defend themselves against less virulent microbes in smaller numbers. (13)

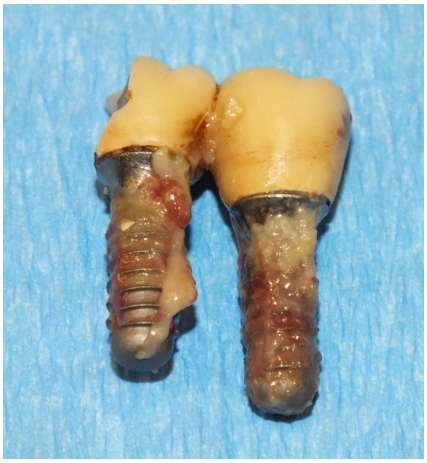

Figure 2: Implants with attached crowns removed from patient's jaw because of peri-implant disease. They are coated with plaque and exudate.

The small size of oral pathogens (±1 micron), their mobility and their ability to rapidly reproduce can pose a significant threat to a patient's oral and systemic health. This is especially relevant when reconstructive dental treatment challenges those patients with difficult to maintain spaces under the gingiva. It would be logical to assume that an optimized fit of implant parts would increase the stability of parts and reduce the size of spaces where oral pathogens might enter and populate. Preventing poor prosthesis margins and subgingival cement may also improve treatment results.

Zipprich (14) has shown how unstable joints can move under function and cause the movement of fluids in and out of the huge internal spaces between implant parts and into the peri-implant environment. It is not difficult to imagine how such movement of oral pathogens and their toxic byproducts could result in a chronic assault on peri-implant tissues and result in peri-implant disease. It would also not be difficult to imagine masses of oral pathogens growing under overhanging margins and in open margins and on subgingival cement.

Blocking access to effective daily plaque removal by poor prosthesis design, misfit implant parts, misfit prosthesis margins and subgingival cement, should be minimized to reduce related complications, like peri-implant disease.

The Root Causes of misfit implant parts, poor prosthesis margins and subgingival cement are "Prosthesis Dimensional Error and the Tissue Effects". These terms were coined and described by Dr. ELA Svoboda in discussions of his research findings. (15,16, 17,18)

Prosthesis Dimensional Error (PDE) is the culmination of all the dimensional errors that go into the making of a dental prosthesis. The size of this 3-dimensional error will vary according to the processes used to make the prosthesis. Earlier technology involving physical impressions, poured models with analogue parts, separated dies, metal castings and porcelain application will have different **PDE** components than those related to milled prostheses made to fit printed models with analogue parts, as created from digital impressions. **PDE** can create a 3-dimensional disharmony between prosthesis connectors and the implant parts that are intended to retain the prosthesis in the mouth. **PDE** is the reason prosthetics "just don't fit right" and need to be adjusted by the dentist during their installation into the oral environment. (Figure 3)

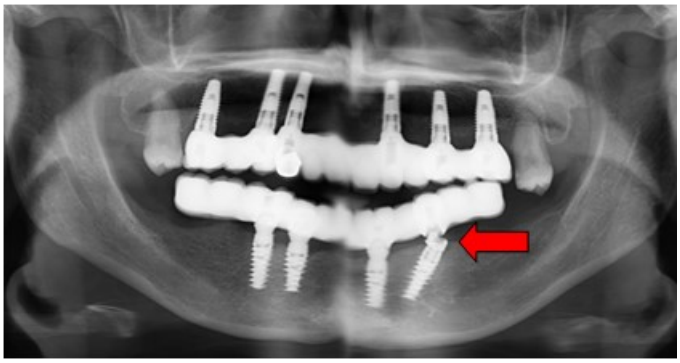

Figure 3: Red Arrow indicates an open connection between an abutment and an all-on-x type mandibular prosthesis.

The expected standard of accuracy for dental models is ±150 microns. (19) Although this model error is expressed using "two dimensional" terminology, it is indeed a 3-dimensional error. This model error alone is 30 times greater than the tolerance for error built into manufactured parts that have obtained Health Canada or FDA approval. Is there any wonder that high precision implant parts constrained within a prosthesis that has been adjusted to fit a dental model, would cause misfits when assembled intra-orally? **High precision parts have an exceptionally low tolerance for error!**

Some dental and laboratory protocols are designed to **reduce PDE** by a **master model technique.** This technique includes a step wherein the prosthesis framework or **registration jig** is sectioned and indexed in the mouth prior to the creation of a new master model, which is deemed to be more accurate than the original model. (Figure 4) While this system can reduce **PDE**, it is time consuming and expensive. The fit of the prosthesis may be better than it would have been without this procedure, but unfortunately the fit of parts still cannot be deemed to be optimized. Jokstad and Shokati (20) found that the vertical misfit between parts was 95 to 232 microns, despite the use of the master model technique.

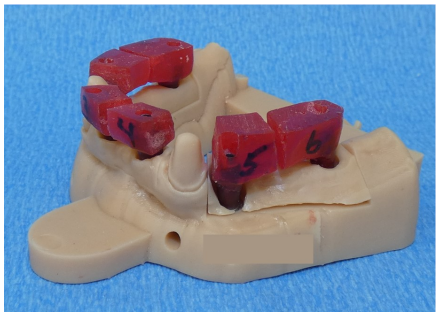

Figure 4: Dental model with a verification jig that can be used to create a master model that represents the mouth.

There are several articles arguing misfits are OK. (3) Misfits may be OK, if it is the best that dentists can achieve. Misfits are probably not OK, if it is possible to consistently optimize the fit of parts by a readily available installation system.

PDE can also contribute to the problem of residual subgingival cement. (15) During the process of intra-oral cementation, the prosthesis may be displaced laterally by contact with adjacent dental units, adjacent tissues, and with the incline planes of their retainers. When margins of a prosthesis are subgingival, the excess cement within the intaglio of the prosthesis can flow along the path of least resistance through the biggest marginal opening and be injected deep into the tissue spaces, where it is difficult to locate and remove.

Tissue Effects: This term was first used by Dr. Svoboda to describe how tissues adjacent to a prosthesis can interact with the implant-abutment parts, abutment-prosthesis parts, the prosthesis and with excess cement during prosthesis installation. These

interactions can all expose the patient to risk factors for complications. He named two clinically relevant **Tissue Effects, Resistance to Displacement and the Gingival Effects**. (8,15,16,17,18,21,22)

Resistance to Displacement (RTD): This is a subgroup of the Tissue Effects that can resist the optimal seating of implant parts and a prosthesis. It may be desirable to organize these effects by the type of tissue involved. Is the **RTD** caused by soft tissues or hard tissues or by gingiva or bone or adjacent teeth or equivalent structures? There are many examples of tissue interactions with abutments and/or prostheses causing open and displaced connections. (23)

Tissue fluids may be displaceable, however when trapped under a prosthesis during its installation, these fluids can enter joints between implant parts and can even displace cement from prosthesis margins. Tissue fluids between implant parts, in implants, in abutments and under prosthetic connectors can become a great substrate for the growth and distribution of invading oral pathogens. By displacing cement from prosthesis margins, these tissue fluids can create voids between the retainer and prosthesis that can be inhabited by oral pathogens**.** (24) All these conditions may foster the development of peri-implant disease.

Gingival Effects: This Tissue Effect was first named by Dr. Svoboda to describe how gingiva interacting with the tissue facing surface of a prosthesis can cause excess cement to become trapped in the gingival crevice, pressurized and propelled deep into the tissue spaces during the process of intra-oral cementation. (21,22)

During intra-oral cementation, the intaglio of the prosthesis is loaded with cement and pushed into place over its intended retainer. As the prosthesis begins to engage the adjacent gingiva, it creates a seal that can trap excess cement that has been expressed into the gingival crevice. As the clinician continues to seat the prosthesis, the gingiva-prosthesis seal intensifies and the excess cement still leaving the prosthesis and the cement already in the gingival crevice is pressurized. This pressurized cement can flow along the path of least resistance, and this pathway often includes the submarginal tissue spaces, where it can be difficult to locate and clean away.

Screw Retained Prosthesis: This term is often used to describe a prosthesis that has been screwed into place onto dental implants during its installation process. This terminology may be confusing, as both cemented-in and screwed-in implant prosthetics are screw-retained by screws attaching abutment-prosthesis complex to implants in the mouth.

Despite this term being used to distinguish the screw-in system of prosthesis installation from the cement-in system, both restorations are essentially screw retained. Indeed, if it becomes necessary to remove a cemented prosthesis, the retaining screw can usually be accessed and removed for that purpose.

In addition, many screwed-in prosthetics have also been cemented onto their abutments or Titanium Bases, in the dental laboratory. So, they are also essentially cemented. As such, the author believes that this terminology should be discontinued as a reference to the method of prosthesis installation and proposes a more precise terminology be used.

Screw-in System of Prosthesis Installation: This term is more precise as it clearly describes the action used to install the prosthesis in the mouth. (15) As well, it clearly distinguishes that mode of installation from the action of intra-oral cementation or the Cement-in System of prosthesis installation.

Complications inherent to the Screw-in Prosthesis Installation System: The Screw-in System of prosthesis installation proposes that the dentist can align and install the prosthesis onto its retaining elements in the mouth in an optimized fashion. Ample research supports that **this is currently impossible** to achieve for multiple unit prosthetics and may only be possible under a few optimal conditions during the installation of a single crown. (Figure 5)

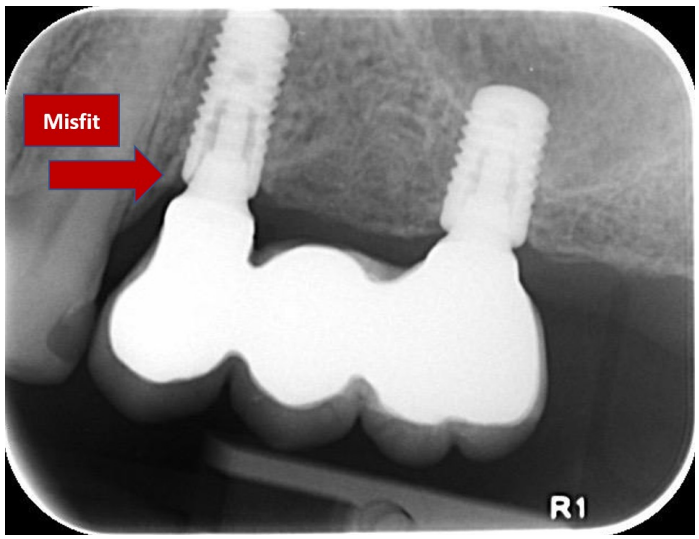

Figure 5: Red arrow indicates implant-abutment misfit on this periapical x-ray image of an implant retained bridge. Image from internet.

The roots of this problem stem from Prosthesis Dimensional Error and are exacerbated by the Tissue Effects. Current manufacturing processes can make implant, abutment, and prosthetic connectors

with a tolerance of ±5 microns. Prostheses are made to fit models that have a tolerance of ±150 microns. This discrepancy in tolerances makes it impossible to optimize the fit of high precision implant parts in the mouth using the current screw-in system of prosthesis installation when the abutment or prosthetic connectors are already attached to the prosthesis. Multiple non-parallel implants may worsen the problem exponentially.

A single crown is expected to be least affected by Prosthesis Dimensional Error. The dentist installing a single unit is faced with adjusting contacts with adjacent teeth within ±5 microns of optimum, while aligning the path of insertion of the abutment channel with the screw channel of the implant, while displacing peripheral soft and hard tissues out of the insertion pathway of the crown without being able to see or feel the implant-abutment connection. This can be exceedingly difficult to accomplish and verify. With the more popular use of platform switch deep sub-bone implants, this system becomes even more challenging for the dentist. Bone can be exceedingly difficult to displace during installation without surgical intervention.

The current screw-in system of prothesis installation is almost guaranteed to cause sub-optimal connections and expose the dentist to significant liability when the patient experiences complications. The prevalence of complications is troubling.

Prosthesis Retrievability: This is a feature of a prosthesis that allows it to be removed from the mouth and reinstalled without any critical damage. It has long been touted as a valuable attribute of implant supported prostheses and has often been used to distinguish the prosthesis that has been installed by the screw-in system from the prosthesis that has been cemented into place in the mouth. However, both screwed-in and cemented-in prosthetics can be made retrievable by including retrievability features in the treatment.

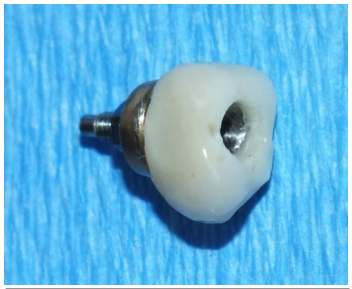

Figure 6: This screw-in crown was removed from the mouth by accessing and removing the screw that fastens the abutment-prosthesis complex to the dental implant.

Retrievability Features: These may include 1) the parallel alignment of dental implants and their congruency with a working path of prosthesis installation, 2) the alignment of implants that brings the screw-access channels to less visible positions for esthetic reasons, 3) the use of non-engaging connecting parts to compensate somewhat for non-parallel implants and their incongruency with the path of insertion of the prosthesis, and 4) the use of angled screw channel assemblies. (25)

All the above retrievability features can be incorporated into restorations that will be installed by either the screw-in (Figure 6) **or cement-in installation process** (Figure 7). In addition, restorations installed by the cement-in system can be luted together with their retainers with temporary cement. This allows for removal of the prosthesis without the need to remove their abutment retainers. It may also allow the prosthesis to be removed without the need to create screw access holes or related cantilevers in the prosthesis.

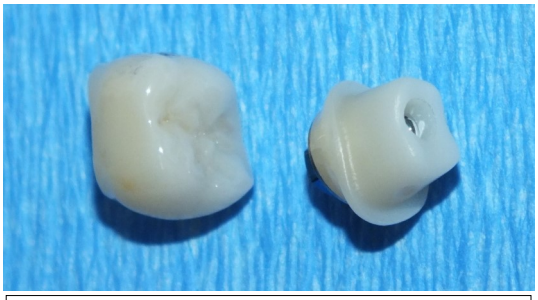

Figure 7: This abutment with the screw access hole, will be screwed to the dental implant and then the crown will be cemented onto it. This abutment-prosthesis complex can be removed from the mouth by removing the attachment screw. The screw may be accessed by drilling a hole through the intact crown or through a plastic cover created for that purpose by the dental laboratory. It is easily retrieved from the mouth.

Cemented restorations can be made with or without plastic covered screw access holes. It is a matter of preference of the treating dentist. Some clinicians may be frustrated with having to frequently maintain these often unaesthetic or worn screw access holes. These plastic cover-screw openings may lack the durability to maintain a stable occlusion. When abutment screw channels are appropriately placed and their positions marked on the prosthesis, it can be simple to gain access to the retaining screw by drilling through the prosthesis when and if necessary.

The author submits that cemented restorations can have more options for retrievability than those installed by the screw-in system. An important advantage of the cement-in system is, that it allows the dentist to optimize the implant-abutment and abutment-prosthesis connections". (17,18) This should reduce the need to access retaining screws for tightening and reduce the need to remove prosthetics for maintenance or treatment of peri-implant disease related to misfit joints or cantilevers that block access to care.

Cement-in System of Prosthesis Installation: This system of installation allows the dentist to install the abutments independently of the prosthesis. This provides the dentist a much better chance of controlling the integrity of the implant-abutment and

abutment-prosthetic connections (18). However, the current system of intra-oral cementation is plagued by poor prosthesis margins and subgingival cement. These are known risk factors for peri-implant disease.

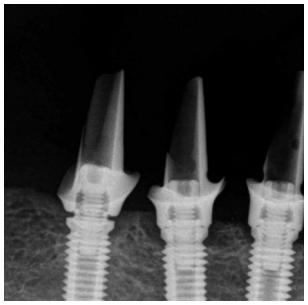

Figure 8: The left abutment was not seated completely on the dental implant. After bone and soft tissue was removed, its fit was then optimized like the other abutments.

Optimizing the Fit of Implant-Abutment Connections: Separation of the retainer installation from the prosthesis installation eliminates **PDE** from that installation step and thus makes it possible for the dentist to optimize the fit of the implant parts. This is unlike the current screw-in prosthesis installation system. (17,18,22)

We must also consider the Tissue Effects (**TE**) when optimizing the installation of the abutments and/or prosthetic connectors. To mitigate the **TE**, it is often desirable to shape the trans-tissue portal. (Figure 8)

Trans-Tissue Portal: This term is preferred over transmucosal portal, as it is more general and includes more than the intra-oral mucosal tissues. Transmucosal terminology appears to have derived from the pharmaceutical industry where it pertains to a route of drug administration. The trans-tissue portal terminology includes all intra-oral tissues, including those that are hard, soft, and fluid, that exist adjacent to or covering the dental implant or healing abutment.

Figure 9: The abutment on the left is a plastic custom healing abutment connected to a Ti Base and designed to shape the trans-tissue portal to accept the abutment on the right.

If the implant, healing abutment or cover-screw are installed and covered with tissues during the implant integration period, then the future abutment connection can be made or developed at the time of the second stage surgery.

The shape of the trans-tissue portal is usually developed by the shape of the outside surface of the healing abutment. If the shape of the healing abutment approaches the shape of the proposed final abutment, the **Resistance to Displacement** offered by adjacent tissues can be minimized. Thus, the optimized fit of the final abutment onto its retaining implant can be easier to accomplish. (Figure 9)

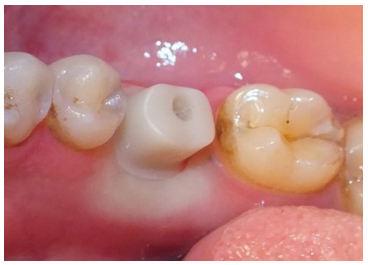

Figure 10: This shows the final zirconia hybrid in place. The tissues are slightly blanched by lateral pressure exerted by the final abutment.

Also, the closer the shape of the healing abutment is to the shape of the final abutment, the easier it is for the laboratory technician to predict the position of the abutment margin in relation to the adjacent gingiva. (Figure 10) I have heard fellow dentists complain, "I cannot find a lab that can position my margins properly". The more the trans-tissue portal varies from the shape of the final abutment, the more the lab technician must guess the position of the gingival margin. The gingival margin generally migrates apically to the occlusal plain of the prosthesis as it is stretched while being tethered to underlying tissues like bone. (Figure 11)

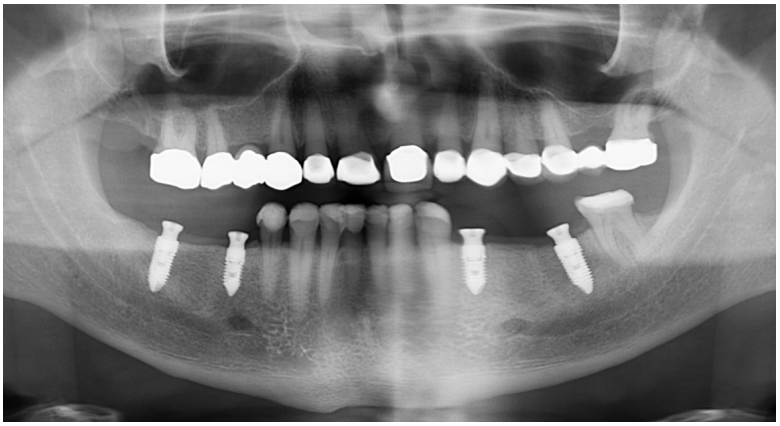

Figure 11: These stock healing abutments attached to platform switch type implants are rather narrow compared to the abutments and prostheses that are to be installed. Without remedial treatment, the resistance to displacement by the adjacent and underlying tissues during installation may prevent the optimal connection of abutments.

The **deeper the trans-tissue portal**, the more likely it will involve adjacent bone that can prevent the abutment and/or prosthesis from seating properly. The lab technician is unable to discriminate hard from soft tissues on a laboratory model. Platform switch implants are currently being placed deeper into the bone to give the technician some running room to develop a working emergence profile. More running room is required when beginning the abutment emergence at a diameter of 3 mm for platform-switch implants, rather than double that diameter for internal hex type implants. This platform-

switch configuration appears to make prosthesis installation more challenging, as the author finds that he frequently must include surgery in this process. (Figure 11)

If the **trans-tissue portal is too narrow**, the adjacent or underlying tissues may offer too much resistance to the abutment during installation, preventing it from seating optimally. Gingiva and bone under the pathway of the abutment during its installation, can be difficult to displace and the resulting implant-abutment misfit can be difficult to detect on an x-ray image due to resolution and angulation issues. Indeed, trying to force the abutment into place may damage the screw and/or cause a separation of the zirconia hybrid abutment shape from its Ti-base. (Figure 9)

In a single stage variation of this shaping process, the trans-tissue portal may be developed by an appropriately shaped healing abutment at the time of implant placement.

What abutment type should we choose? There are many choices from the simple stock abutment to a custom abutment to a "well designed" custom abutment. Customizing the shape of abutments and complimentary prostheses has been made much easier and more consistent than ever by CAD/CAM technology. Some might like to argue that this technology surpasses the casting technologies in its ability to create consistently excellent implant parts that fit with a high degree of accuracy.

Stock (final) abutments can be made with implant connectors with a high degree of precision and their profiles are often like those of **stock healing abutments.** As such, they are often easy to install optimally onto dental implants in the mouth. Resistance to Displacement (RTD) by adjacent tissues can be small. (23)

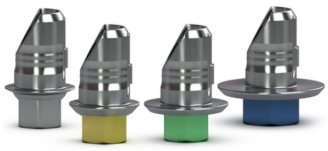

Figure 12: Precision made Ti bases made to fit different diameters of Biohorizons implants.

However, the narrow stock abutment often relies on the prosthesis to develop the emergence profile. This means that the prosthesis must displace the adjacent tissues laterally during installation, and in the case of bridges also compress the tissues under the pontic regions. These tissue interactions can prevent the prosthesis from seating properly and the lateral displacement of tissues often causes them to bleed. When the dentist attempts to check the quality of the fit of the margins in the mouth, this may also cause tissue injury and bleeding. RTD and PDE can already make prosthesis installation challenging.

In addition to the limited shapes of stock abutments and the limited ability to modify those shapes, their use often results in lack of control of margin location and design. Thus, it is almost impossible to mitigate the Gingival Effects to prevent the advent of residual subgingival cement, cement displacement from the margins, and open and overhanging margins.

Figure 13: This is a titanium blank with a premade high precision implant connector (red arrow). The part above the arrow can be milled into a custom abutment shape.

Titanium base (Ti base): Almost every major implant company have Ti bases and titanium blanks available that fit their implants. These are high precision-made parts that can be connected optimally to an implant and cemented to a custom shape in the dental laboratory. (Figure 12,13)

Their weakness appears to be the cemented connection between the titanium base and the abutment shape or prosthesis. These parts have been known to separate during installation and under function. If the Ti base is connected directly to the prosthesis in the lab, the prosthesis will need to be installed by the Screw-in System of installation and will thus be subject to all the problems inherent to that system.

Ti base with custom abutment shape: This combination often involves the use of a zirconia custom abutment shape cemented onto a Ti base in the dental laboratory. The custom zirconia shape can be much more esthetic under the gingiva than a solid titanium abutment, as the latter may cause a grey hue in the overlying gingiva. Both titanium and zirconium appear to be highly biocompatible, as gingival epithelium appears to be able to form a tight connection with their surfaces. (Figure 14)

Figure 14: The custom white zirconia shape has been cemented on a Ti Base (Figure 12) while on the right, the shape has been milled from a Ti blank unique to each implant connector type (Figure 13).

Aesthetics can be enhanced when the prosthesis is milled from the same zirconia block as the abutment shape. This can render the connection between the abutment and prosthesis difficult to discern by the patient.

Titanium blanks: Titanium blocks usually have high precision-pre-made implant connectors that are specific to each implant type. (Figures 13&14).They are an alternative to the use of Ti bases for dentists who want to avoid the cemented connection between the Ti base and the abutment shape. They might be a great choice for use in the posterior maxilla and mandible where functional loads are higher and aesthetic demands of the patient are lower. Titanium blocks lend themselves to customization by CAD/CAM procedures that are consistent with today's digital workflows.

It is also possible to mill an abutment-prosthesis complex out of such a blank. This would render the prosthesis a metal color and its installation process would suffer the same problems as those installed by the Screw-in System of installation. (Figure 14)

Complications Related to the Cement-in System of Prosthesis Installation: The current cement-in installation system can allow for the optimization of the implant-abutment connection and it can reduce the Resistance to Displacement by adjacent tissues using appropriately shaped healing abutments that can facilitate the installation of custom abutments. However, current systems do not have a means for mitigating Prosthesis Dimensional Error or the Gingival Effects. Current systems thus can and do expose patients to problems related to open, overhanging, and overextended margins, and residual subgingival cement. (Figures 15 & 16)

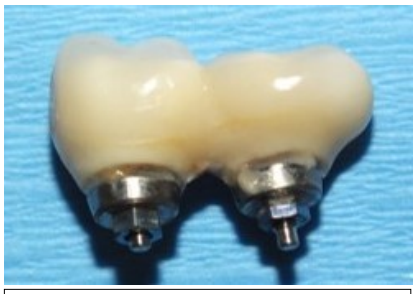

Figure 15: These splinted crowns were removed from a patient and show both open margins and submarginal cement.

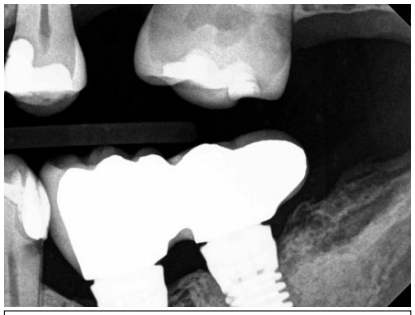

Figure 16: This is an x-ray image of Figure 15 in the mouth with open margins under the crown profiles.

Reverse Margin System of Prosthesis Installation (RM System): The Reverse Margin System of prosthesis installation has been specifically designed to be sensitive to and to mitigate the negative effects of the root causes of complications. These root causes have been defined as Prosthesis Dimensional Error and the Tissue Effects. The Tissue Effects include Resistance to Displacement and the Gingival Effects. These root causes of complications have been defined above. (17, 18, 22, 23) (Figures 17 & 18)

The Reverse Margin System offers a solution to the problems inherent to both the current Screw-in and the Cement-in prosthesis installation systems. The RM System makes it possible for the dentist to consistently optimize the fit of implant parts, reduce or eliminate open, overhanging, and overextended margins, and prevent residual submarginal cement. These are all known risk factors for peri-implant disease.

The Reverse Margin System of Prosthesis Installation is thus proposed as the basis of a **New Standard of Care.**

This author would go on record to suggest, that continuing to use the current Screw-in System of prosthesis installation where implant-abutment or abutment-prosthesis misfits are almost guaranteed and the current Cement-in System where open, overhanging, and overextended margins and residual subgingival cement are common consequences of treatment, are outdat-

Figure 17: An experiment was conducted to compare the Reverse Margin (RM) and the Chamfer Margin (CM) in their efficacy in preventing the occurrence of submarginal cement when the margins were placed 1 mm below the gingiva. RM on the left clearly outperformed the CM both in vitro and in vivo.

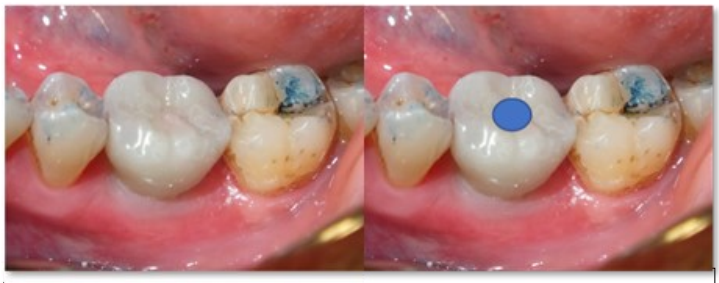

Figure 18: Picture on the left shows a RM zirconia crown cemented into place over the RM abutment shown in Figure 10. The image on the right depicts the same first molar crown with an optional simulated plastic covered screw access hole.

ed and need to be abandoned. They put patients at risk of serious complications and dentists at risk of liability for those complications.

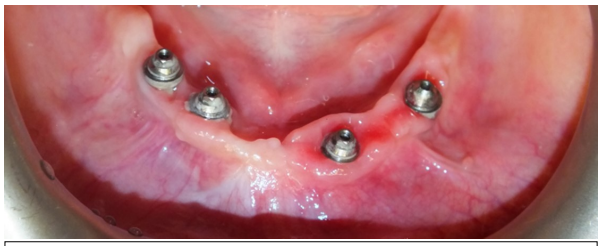

Figure 19: This picture shows multiunit abutments in place. The prosthesis has already come off as a result of broken screws. Note the plaque and inflammation in the peri-implant environment.

Upgrading the Current Screw-in and Cement-in Prosthesis installation Systems: To derive benefit from our new knowledge of the root causes of complications, let us explore how mitigating their negative effects is accomplished by adding some unique design and protocol features to the current Cement-in system.

The RM System allows dentists to fully exploit the amazing accuracy afforded by existing technology and is robust enough to safely integrate the use of prosthetics made by older technologies. The RM System may also be relevant in the future because this system can accommodate an even more precise fit of abutment parts. The current Screw-in System cannot accomplish this, as increased precision of implant parts would result in an even lower tolerance for error, and a higher degree of difficulty for the installation of the prosthesis.

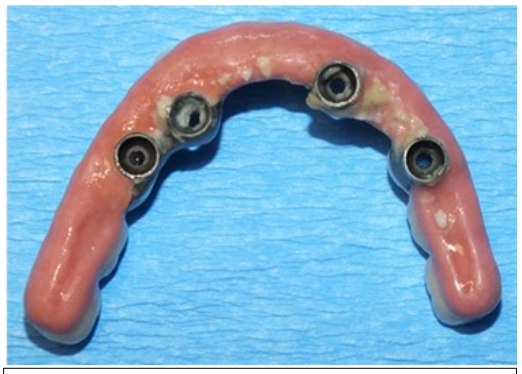

Figure 20: Note the inaccessible plaque in the peri-implant connector environment.

The RM System is rooted in solving a microscopic problem by logic. It helps the dentist divide the installation process into manageable parts that are easier to execute in the mouth in an optimized fashion. It also facilitates explaining how the optimization of the installation process was accomplished, should this need arise. This would likely reduce the dentist's liability for damages that may occur as an unintended result of treatment.

All-on-X Installation: It is of great concern that the All-on-X prosthesis installation is based on the current Screw-in System. As a result, it puts the patient at risk of misfit abutment-prosthesis connectors that are often placed in the equigingival and subgingival regions in the mouth. (Figures 19,20) In addition to this serious shortcoming, it is common that this system requires the prosthesis to cantilever off the implant base to allow for aesthetic screw access holes. Since these screw access holes can weaken the prosthesis framework, it is also not uncommon to increase the width of the prosthesis to strengthen it. (Figures 21,22)

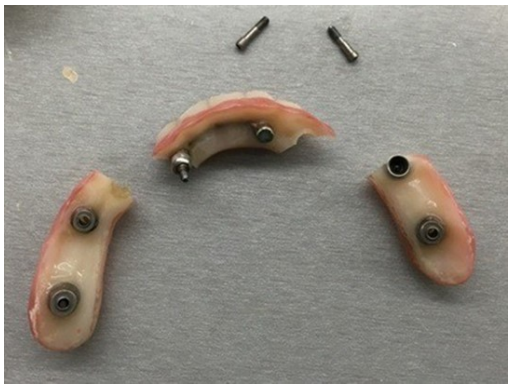

Figure 21: Note the fracture locations where the framework was too narrow and weak. Image from Bauersmiles.com

Misfit parts with cantilevers that amplify the stresses on misfit parts might not be ideal if the fit of parts could have been optimized. In addition, cantilevering the anterior of the prosthesis off its implant base makes the prosthesis profile wider and can block access to effective care by the patient and by the dentist. Plaque is a known risk factor for peri-implant disease. We already know there is no predictable treatment for peri-implant disease (7) and thus current processes of revisional care can be unreliable, uncomfortable, and expensive.

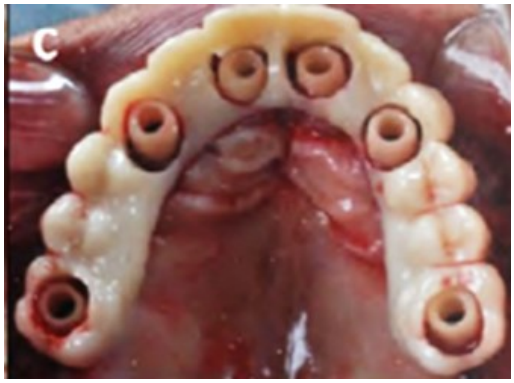

Figure 22: Note the bulky zirconia implant abutments. This framework will need to be wider for strength. Will the tissues be accessible for cleaning? Image from internet.

In addition to the abovementioned problems, dental surgeons often remove abundant hard and soft tissues to adapt the gingival-prosthesis junction to the smile line. The author would like to reiterate that tissue removal is much easier than tissue addition. Thus, when peri-implant disease begins to manifest around implants placed in vertically reduced bone, there may be little left to smile about. Revisional treatment options may be limited and treatment results may be less than satisfactory for the patient in this predicament.

Prosthodontic Options Classification: Carl Misch published a classification system to describe various prosthetic reconstruction types. An FP-1 case describes a type of prosthesis that would replace only lost tooth material. A FP-2 would replace

tooth material plus some adjacent tissues by lengthening the tooth and/or adding some gingiva-colored material to the tooth. An FP-3 prosthesis replaces teeth plus a more extensive volume of lost tissues than a FP-2 prosthesis. These lost tissues include gingiva and underlying bone mass. (26)

The internet gives examples of dentists converting possible FP-1 prosthetic cases to FP-3 cases to attain a more aesthetic smile for the patient. The conversion of FP-1 and FP-2 cases to FP-3 cases should only be considered when the patient fully understands the prevalence of complications and has been presented with alternative solutions. There should be full disclosure about research indicating that patients can experience 15 times the peri-implantitis rate experienced by those with less extensive prostheses configurations. (7)

This treatment modality could be supported where existing clinical conditions are amenable to an FP-3 prosthesis-based reconstruction without extensive hard tissue removal. This support is contingent upon the clinician showing how they will optimize the fit of implant parts and provide the patient with access to effective homecare. For this purpose, consider "Installing the All-on-X Prosthesis the Svoboda Way".

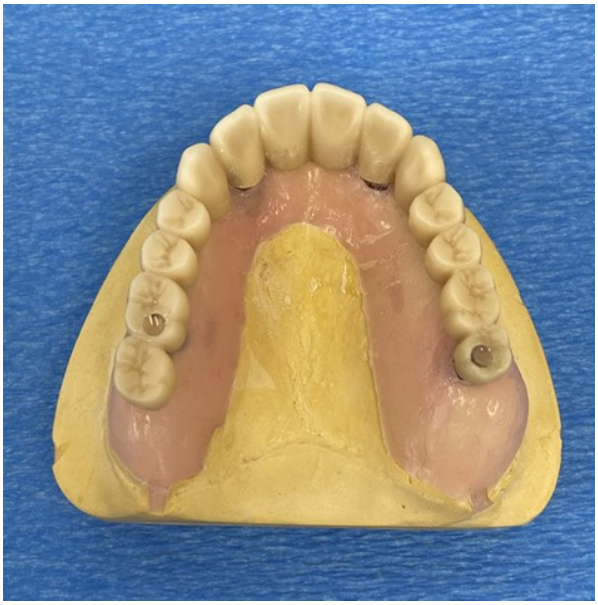

Figure 23: This all-on-x installation system has reduced the prosthesis profile for easier maintenance, made it possible to optimize the fit of connections with the prosthesis while keeping it easy to retrieve. This prosthesis was installed the Svoboda Way.

Installing the All-on-X prosthesis the Svoboda Way: This System of prosthesis installation was developed to be sensitive to the root causes of complications and was first described by Dr. Emil LA Svoboda. (17,18) The "X" refers to the number of implants used to support the fixed prosthesis. This number often describes 4 to 6 or more dental implants placed to retain a multiple unit fixed prosthesis. Each implant retainer is usually connected to a multi-unit abutment (non-engaging, angled or straight) installed in the mouth and then combined with prosthetic-connectors that were embedded in the prosthesis, in the dental laboratory.

Implant Parts: The abutments and prosthetic connectors can be referred to as implant parts, as they are mass-produced with high precision connectors that are intended to connect to the dental implants. They are usually attached to each other by screws.

The Svoboda Way describes a method of installation where the prosthesis is designed to allow the dentist to pick-up the prosthetic connectors in the mouth rather than have them attached to the prosthesis in the laboratory. This allows the dentist to consistently optimize the fit of implant parts and achieve the passive fit of the prosthesis in the mouth. (17)

The Svoboda Way of prosthesis installation for All-on-X cases eliminates the negative effect of **PDE** on the fit of the implant parts, by not having the prosthesis attached to the implant parts prior to its installation. By installing all the implant parts onto the implants in the mouth prior to attachment of the prosthesis, the **fit of implant parts can be consistently optimized**. This is simply not possible by current published screw-in multiple unit prosthesis installation processes. (Figure 23)

To facilitate the above process, the laboratory technician must anticipate the expected **PDE**, and create enough cement space between the prosthetic retainers and the prosthesis on the dental model. This is to allow the dentist to fit the prosthesis over the prosthetic connectors when installing the prosthesis in the mouth. However, **the technician should not attach the prosthetic connectors to the prosthesis in the lab.**

Once all the implant parts are installed, the space created by the laboratory technician will allow the dentists to place and remove the prosthesis from the mouth while adjusting for tissue compression by the prosthesis, fit over the prosthetic connectors and occlusion. After the fit and occlusion are deemed optimal, the dentist can then cement the prosthesis into place. After the cement sets, the prosthesis can be easily unscrewed from the mouth, refined and re-installed. **This Svoboda Way process of prosthesis installation results in a prosthesis that fits passively in the mouth.**

This system of installation would be recommended for those cases where the clinician is able to provide the patient with effective access for effective daily maintenance of the peri-implant environment. Where this cannot be done, I would like to recommend another variation of the Svoboda Way installation technique. This variation is specifically designed to improve the patient's access to the peri-implant environment for the purpose of daily maintenance.

The Svoboda Way Variation for All-on-X Cases where access to peri-implant care would otherwise be compromised: Access to care may be compromised by the removal of tissues for the purpose of aesthetics or to access a greater volume of bone for better initial implant stability. This can result in large prosthetic cantilevers needed to move teeth into positions for better lip support and for access to palatal/lingual screw-access channels for easy prosthesis retrievability. (18)

The Svoboda Way of installation previously discussed, already offers the dentist a way of optimizing the fit of implant parts and a way of providing the patient with a passive prosthesis that is easily retrievable. (17) However, plaque is a known risk factor for peri-implant disease (7) and thus access to care is important to reduce complications and dentist liability for those complications. (18)

Dr. Svoboda proposes that the implants be placed in line with the ridge, rather than lingual/palatal to the ridge, to narrow the prothesis profile and to use a cementation process, to attach the anterior of the prosthesis to the retaining implants. This prevents the need for lingual/palatal screw access holes.

A temporary cement can be used to maintain easy retrievability, while providing retention and blocking access to the abutment-prosthesis space by oral pathogens. Since it can be difficult to predict the abutment-gingival margin relationship, it might be best to use the Reverse Margin System designs and installation protocols, to prevent open margins, overhanging margins and the advent of submarginal cement. These are all known risk factors for peri-implant disease. Perhaps it is time to stop or reduce the use of downward facing margins for implant restorations in favour of the Reverse Margin™ System. (22)

In Summary: All the above terms and recommended installation protocols are based on understanding and mitigating the negative effects of the root causes of complications. These root causes are also relevant to the treatment of natural teeth.

The new terms that have been created by the author, are intended to make it easier to identify and discuss the root causes of prosthesis installation problems and their intended remedies. Indeed, Prosthesis Dimensional Error (PDE) and the Tissue Effects (TE) need to be considered whenever an installation process is contemplated. The first question should be, "How does this process deal with PDE and the TE?" When prosthetics are to be cemented, the Gingival Effects need to be considered as well. It is time for the Profession to vet the merits of this new knowledge and usher in a new and better Standard of Dental Care for patients worldwide.

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