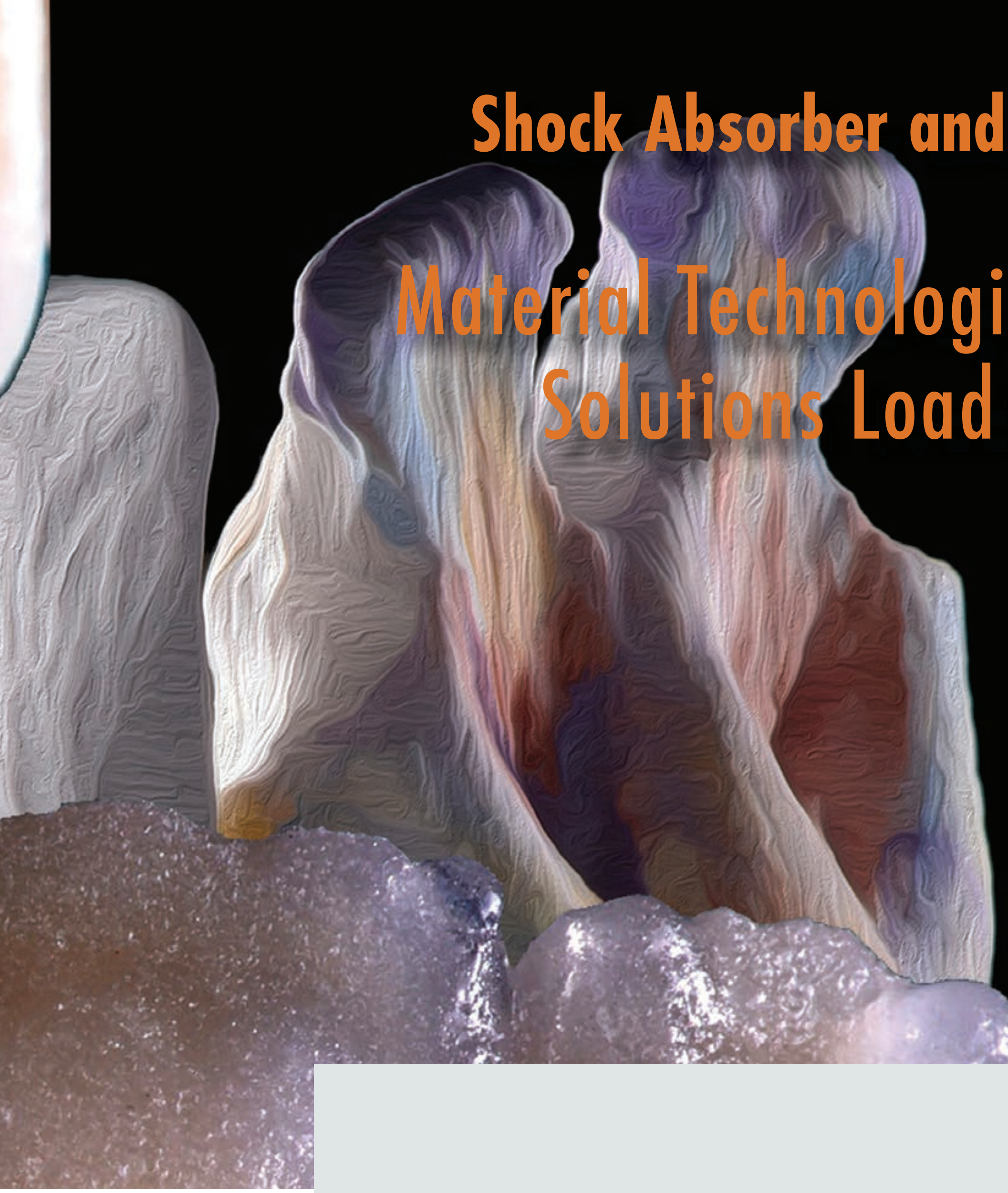

Shock Absorber and Ceramic Zirconia: Part One: Material Technologies and Original Solutions Load Rehabilitations

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The objective is to describe the motivations and use of original solutions in working with, treating, and using zirconia-ceramics in prosthetic dentistry.

Foreword

The somewhat "full-bodied" article was developed, realized and proposed in two parts. The first part is a monograph, where the aspects related to the technology of the materials and the motivations that led us to deepen our knowledge of them to be able to "exploit" them to the fullest. While in the second part, entitled "Designed and Solved Clinical Cases," which will be published in the next issue of dental dialogue, we will present some designed and solved clinical cases using what is described here (Fig. 1).

Introduction

We are going through years of transition from established prosthetic dentistry that has always used materials and methods of various kinds in an analog form to prosthetic dentistry that makes use of techniques, materials, and processes that are increasingly computer-digital (Figs. 2 and 3).

In this article, divided into two parts, we will address practical aspects used in our laboratory and practice activities that have been confirmed crucial to technical and clinical success (Fig. 4).

Choice of connectors for crowns or implant frameworks: only long connectors with the overall height of about 2/3 of the tooth element should be opted for, never short connectors (Fig. 4a).

Fig. 1


Fig. 2

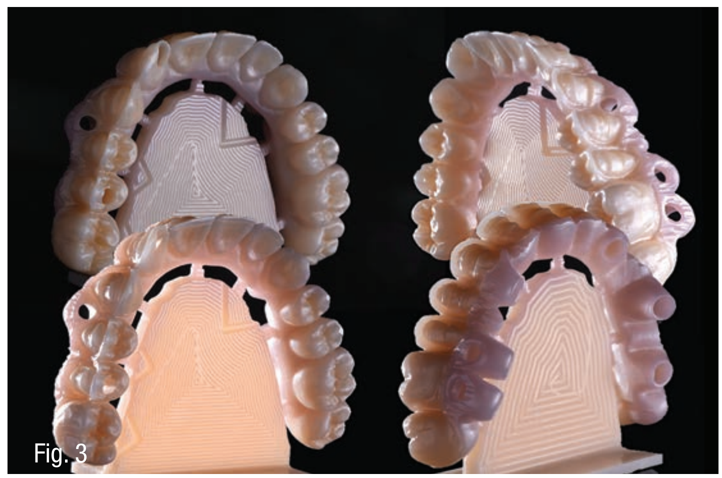
Fig. 3


Fig. 4

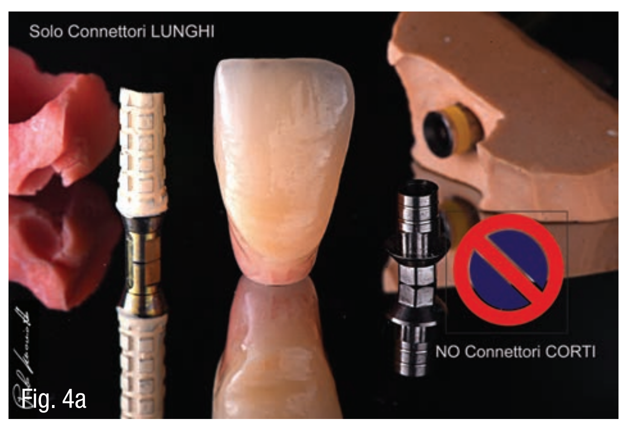

Fig. 4a

This first monographic part mainly discusses the dental aspects. Some techniques and procedures are based on methods that are always very current; for example, the practice of layering all prosthetic devices in images is a pictorial method devised by the Flemish artist Jan van Eyck in the year 1400. In 1200, the "young Leonardo son of Bonacci," called Fibonacci, discovered an original series of numbers in succession. For 700 years, no importance was attached to it, until in 1900 they found that one could apply it, for example, in the golden section! Techniques, methods, and dated knowledge are often forgotten but always very useful if carried over even in the fabrication of our prosthetic devices (Figs. 5 and 6).


Fig. 5

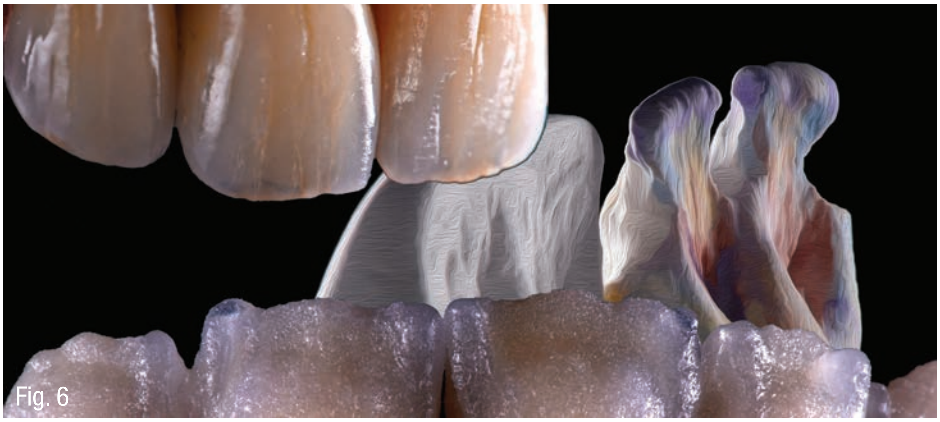
Fig. 6


Fig. 7

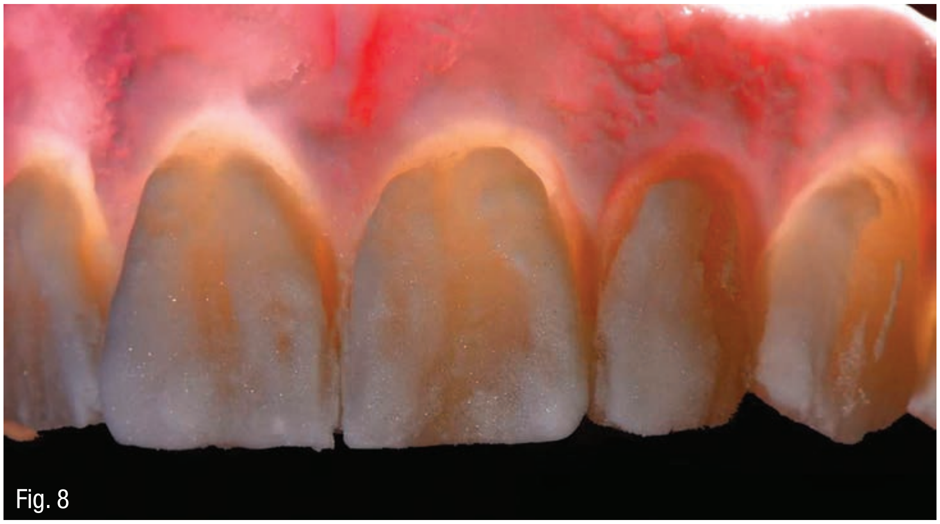
Fig. 8

The question then is:
Are we sure that quick and correct calculations and procedures can be done only using algorithms, computer means and various computers?

Our answer in dental specifically is based on the careful analysis of what is being proposed in the international arena by authoritative research centers, and we can summarize it as follows:

More and more CAD: CAM + handmade solution is better.

More and more use of digital systematics is associated with skills and creativity of the human brain and our hands, the only "tools of the tools" capable of achieving the "infinite" individual solutions we are called upon to address.

In such a vast field, we trust that what is proposed can help to give the correct input to the knowledge needed to better cope with daily work without incurring the unnecessary, dangerous and sometimes tragic "risks" that can occur if all possible "variable" situations of the case are not taken into account (Fig. 7). Another valuable tool at the constant integrity check of our rehabilitations is also transillumination (Fig. 8). According to functional theory, form in nature is dictated by function, which was already well present in the writings of Aristotle. However, over the years, this theory has been countered by the formal approach of Etienné St. Hilaire, in which it is a form that induces a specific function and enables a healthy evolutionary process.

Bionics, a science that studies the structure and functions of living organisms to derive valuable elements for making technological devices, inherits the two theories and applies them in the field of the human.

Prosthetic dentistry expresses the principles of formal therapy and bionics with the peculiarity of inserting "prosthetic devices" into a dynamic system.

We believe it is of primary importance to know the chemistry, physics and mechanics of new materials to design and fabricate excellent prosthetic devices without unpleasant pathway inconveniences. We will endeavour to explain how to apply Lagrange and Dirichlet's theorem to clinical and technical professions. As highlighted in image 9, this theorem describes an environment where we can achieve stability and pursue a goal with calculations and considerations that identify global maximum, local maximum, local minimum, and global minimum (Fig. 9a).

Lagrange and Dirichlet's "stability" theorem in mechanics establishes a

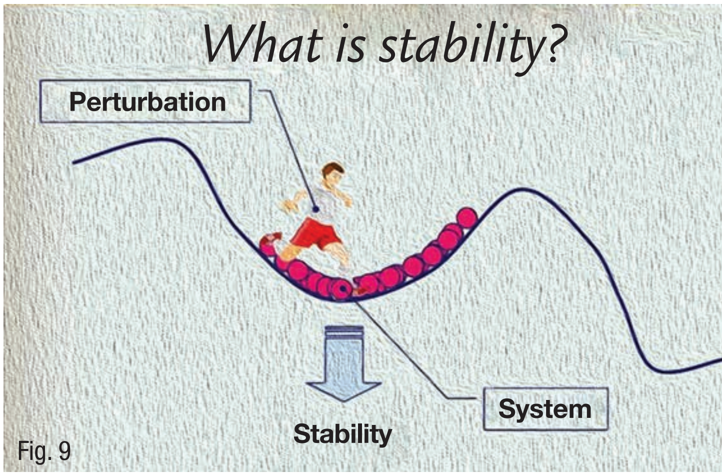

Fig. 9

- ✓ Stability is a basic concept of physics.
- ✓ This concept is totally applicable in testing control systems. It refers to the tendency of a system returning towards a state of equilibrium from where the system has been moved from.

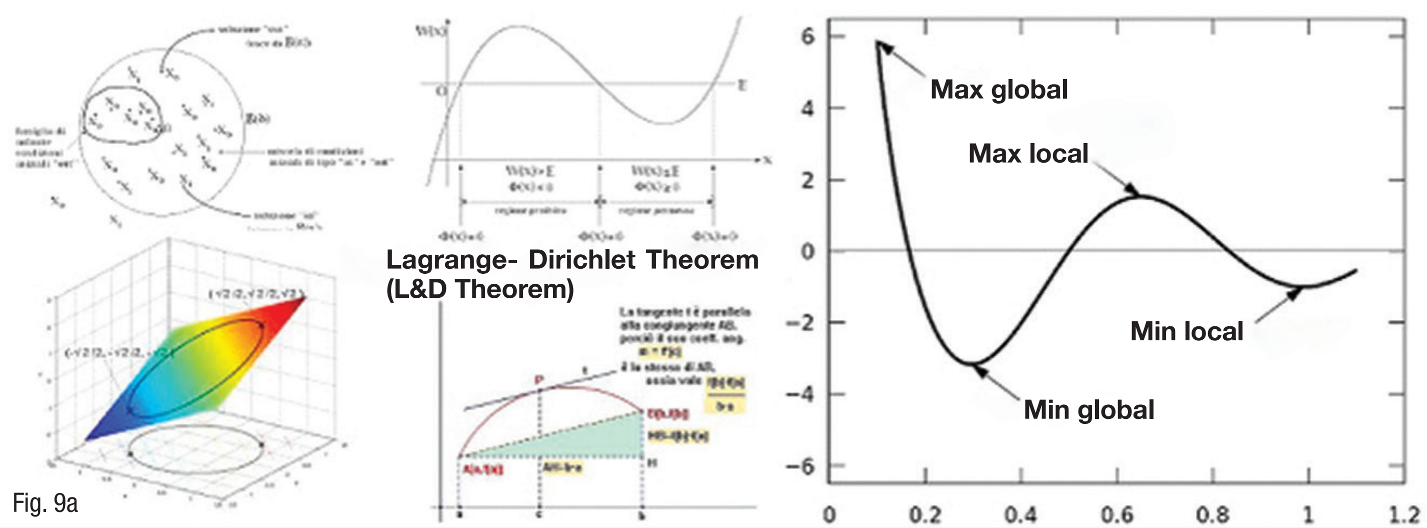

Fig. 9a

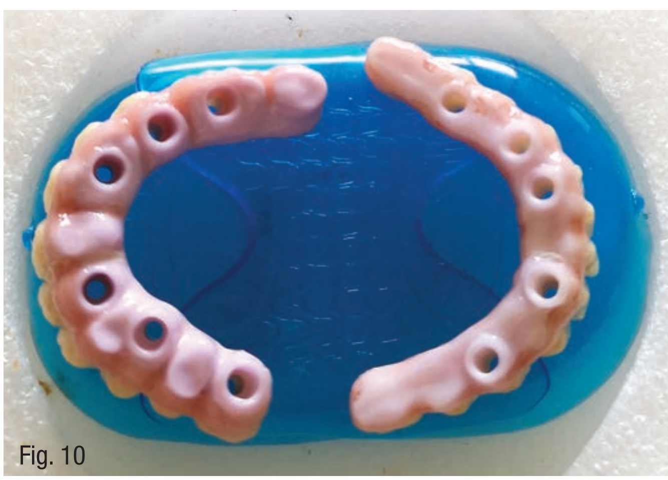
Fig. 10

criterion of sufficient stability under equilibrium conditions. The theorem was named after their authors, Joseph Louis Lagrange and Peter Gustav Dirichlet. Joseph Louis Lagrange, whose real name is Giuseppe Luigi Lagrangia, from Turin, born in 1736 and died in Paris in 1813, was an Italian mathematician and astronomer who was very active in scientific research. He lived for years in Berlin, then in Paris, where he changed his name.

A "brain on the run" even then. As we see, men, with their abilities their aptitudes to exchange their knowledge and acquire new knowledge, have always been there and will always be there. It is certainly not a law or regulations that can create this experience abroad. Still, it is a desire that is born within us, and that can be developed harmoniously without the need for unique constraints. Lagrangia is considered one of the greatest and most influential European mathematicians of the 18th century.

His most important work is "Analytical Mechanics," published in 1788, with which rational mechanics was conventionally born. In mathematics, Lagrangia is remembered for his contributions to number theory and for being among the founders of the calculus of variations. Gustav Dirichlet, whose paternal family came from the village of Dirichlet in Belgium, was born in Düren, where his father ran the post office. He was educated in Germany and then in France, where he had as teachers many famous mathematicians of the time.


Fig. 11

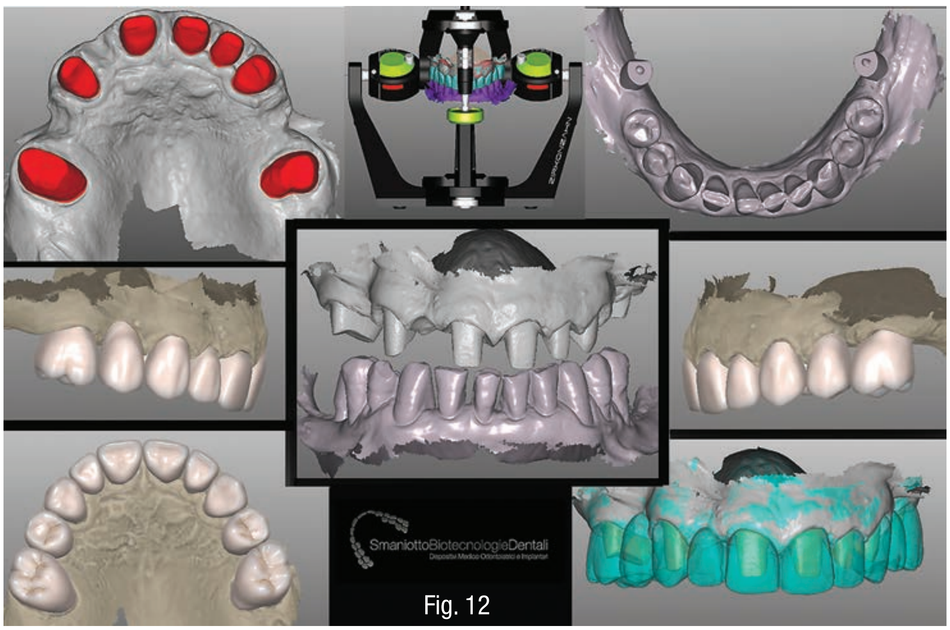

Fig. 12


Fig. 13

To understand the prosthetic materials we are using Today, we need to understand the influence of the Lagrange - Dirichlet theorem on using these materials. Therefore, these scientists studied the physical and mathematical formulas for making the variables that there can be in a complex dynamic system coexist together in active systems. The Lagrange - Dirichlet theorem describes how we find stability in prosthetic devices (Figs. 9 and 9a), where the prosthetic rehabilitation of the arches is composed of various metallic and non-metallic materials. In this device, industrially manufactured metal connectors are bonded to a zirconia framework covered with feldspathic ceramic (Figs. 10 and 11).

Prosthetic rehabilitations are complex dynamic systems that act within our oral cavity and are moved by the elevating and lowering muscles of the tongue, cheeks, etc. Lagrange and Dirichlet proposed a theorem, not for dental use, but to make everything that was self-propelled work best through rail systems made of multiple mechanical parts: wood, metal, wheels, motors, all complex systems that had to have stability in their complexity, realizing a stable mechanical equilibrium system (the mathematician and physicist Ljapunov also defines a scalar function used to study the stability of a point in equilibrium in a dynamic system that fits the stability in the equilibrium of a complex dynamic system such as the hollow-oral rehabilitated with prosthetic devices).

Stability refers to the tendency of a system to return toward the equilibrium state from which it had been removed by a perturbation and is a fundamental concept of physics fully applicable to our analog and digital control systems. In the diagram (Fig. 9a), the Lagrange - Dirichlet theorem is schematically illustrated: stability is within a range we can control. Outside this stability range, various inconveniences such as cracks, fractures, and exfoliation must be strictly avoided. In dental technology, metallic and non-metallic materials are utilized. Currently, among non-metallic materials, zirconia, a bioinert ceramic material, has taken over.

Fig. 13a

Fig. 13b

Fig. 14

The bioinert ceramic materials we use, such as zirconia and glass ceramics, are inorganic, polycrystalline, amorphous materials with high hardness, high melting temperature and low thermal conductivity with high hardness, high melting temperature and low thermal conductivity with biomechanical applications in orthopedics and dentistry (Figs. 12 and 13). American National Standard Institute, an accredited research and validation centre, explains in detail why zirconia was manufactured (Fig. 13a).

Zirconia is a heterogeneous polycrystalline ceramic with high mechanical strength. Its physical and chemical characteristics have enabled its wide use in dentistry. It occurs in nature in three different configurations:

Analog vs Digital

two worlds to cross, to understand, and to relate to each other

Fig. 14a Art work by Fiorenzo Bacci – www.fiorenzobacci.it

Fig. 15

Fig. 16

Fig. 17

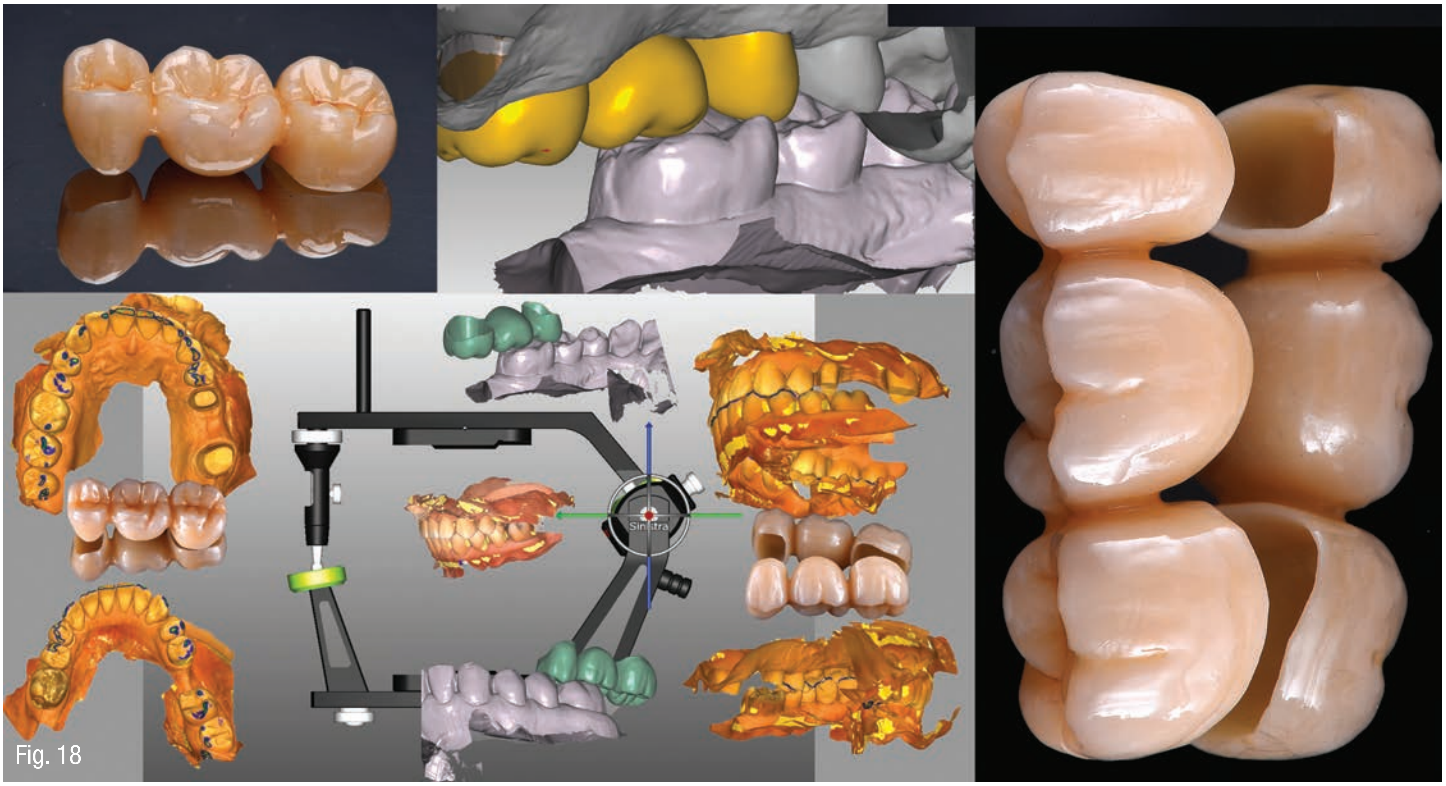

Fig. 18

cubic (at a melting temperature between 2680° and 2370°), tetragonal (2370° to 1170°) and monoclinic (1170° to room temperature). Each of these allotropic stages has different mechanical and physical characteristics.

Our indirect restorations are generally more made in the form yttrium-stabilized tetragonal (Y-TZP). In the presence of mechanical, thermal, or combined stresses, a phase transformation to the monoclinic form can occur with a 4-5% increase in crystal volume and the formation of internal stresses of a compressive nature. In prosthetic devices, this aspect is an advantage because it leads to "self-repair" of the zirconia by blocking the

Fig. 18a Volumetric Calibration Translumination + L&D Theorem

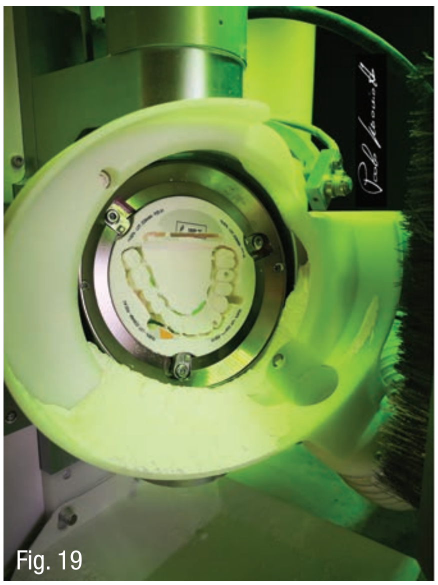

Fig. 19

Level one Diagnostic Technique

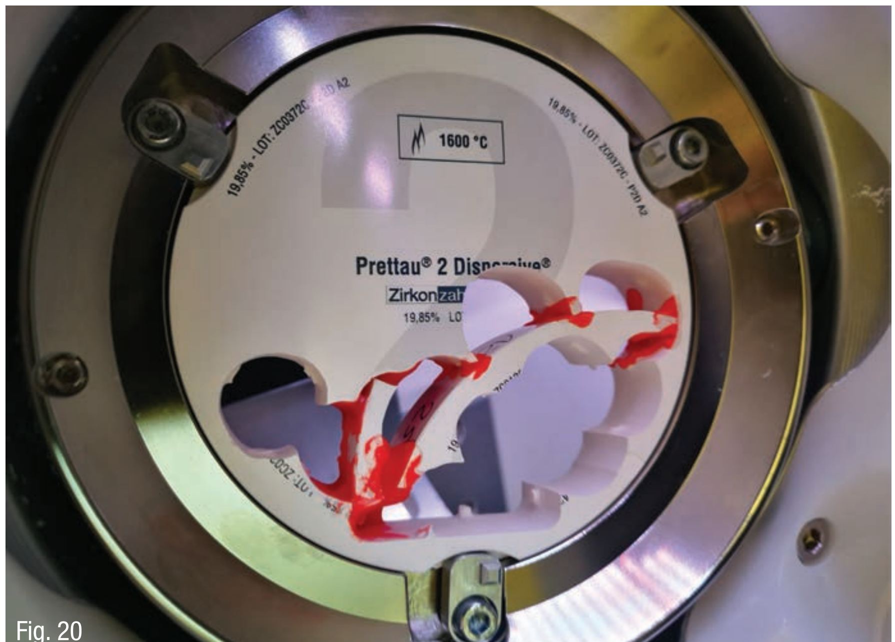

Fig. 20

Advantages of a pre-planned maintenance based on the vibrations are evident and numerous

propagation of any micro-cracks, an example of the stability of a dynamic system. Phase transition can also occur at room temperature in the presence of moisture, causing irreversible deterioration of zirconia properties. Industries are geared to manage or retard with different types of "stabilizers" this aging process.

The development of zirconium oxide-based tenacious bioinert ceramics aims to produce materials to obtain micro- and macro-structures capable of giving them superior mechanical and tribological properties compared with those used a few decades ago (Figs. 13b and 14). What has been described before makes it possible to manage methods, materials, and techniques that are indispensable Today in the coordinated management of digital CAD-CAM technologies, making it possible to move from the metastability of the zirconia to the stability of the prosthetic device as a whole clinically and technically.

Zirconia milling can take place in the "soft" or "hard" form, the most widely used being the "soft" form, as it is manageable by the usual CAD-CAM milling machines available in dental laboratories. State-of-the-art disposed of analog and digital systems. Analog is governed by our brains (algorithm acting through human knowledge, sensitivity and manual dexterity), while digital delegates design and executive phases to the mathematical management of special programs that govern CAD - CAM machines.

Since our profession is called upon to make "unique one-off pieces," the combined analog and digital arrangement enable us to accomplish what is described below:

Analog/Digital: two terms, two worlds, to cross interpenetrate, put in relation. (Fig. 14a).

Established traditional analog knowledge coupled with digital

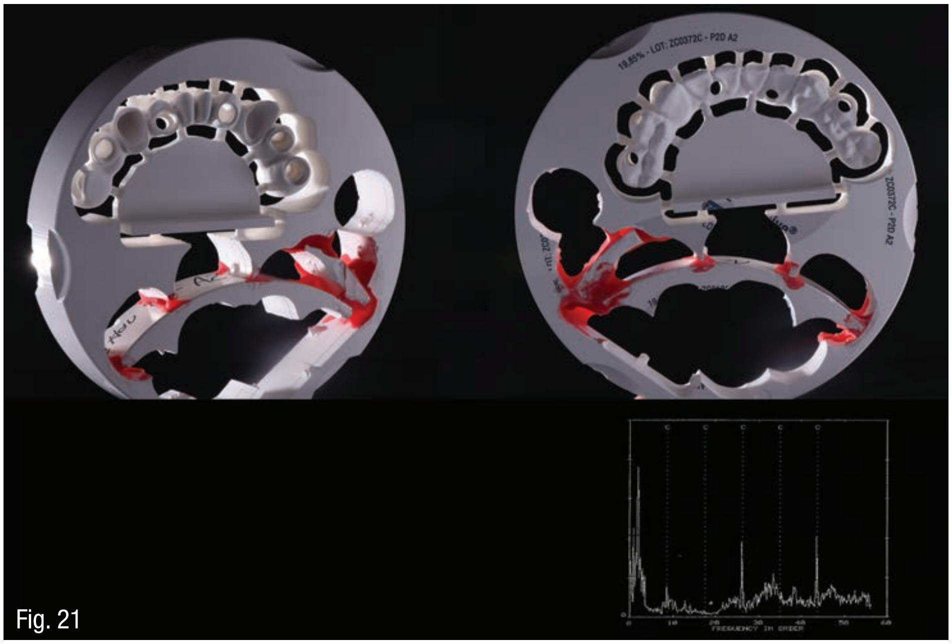

Fig. 21

Fig. 22

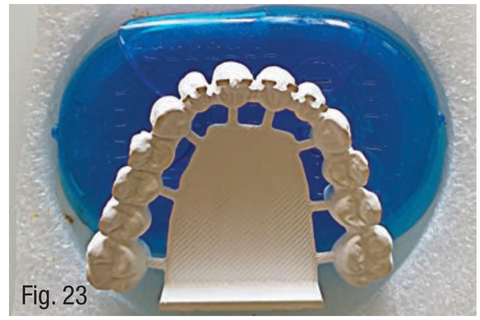

Fig. 23

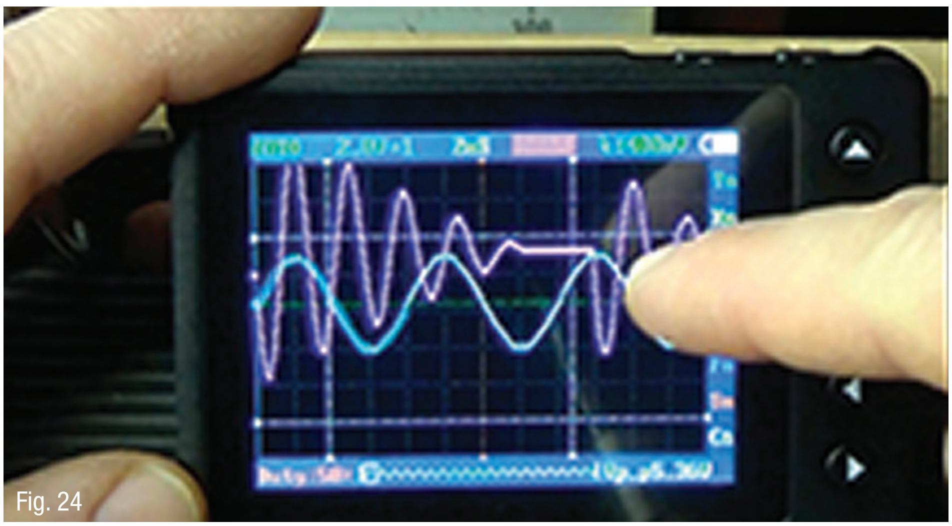

Fig. 24

technologies enable results and verification that were once unattainable (Figs. 15 to 17). After properly designing our prosthetic devices, we aim to make them "live" as long as possible. With zirconia, we can meet not only aesthetic but also functional goals by being able to recreate correct occlusal morphologies.

Zirconia, concerning the types of abrasive, adhesive and erosive wear in the occlusal/functional field, has excellent tribological properties, i.e., wear resistance (Fig. 13b). As described in these images, the ability to resist wear types is related to all the fabrication steps, especially the careful surface polishing (Fig. 18). The images as described in the cited articles (Fig. 18), illustrate the need to remove post-sintering surface roughness with special rotary tools and abrasive pastes and highlight the quality of polishing in the 4 surface passes:

1. Grinding
2. Satinized (both with cutters abrasive cutters with scaled grain size)
3. Polished with rubbers
4. Diamond polished with felts and diamond pastes

Our devices should present themselves with an excellent quality of post-sintering surface polish (See previously described treatment steps), which, together with the final glazing, will give the prosthetic device a very low abrasiveness "tribological capacity" toward antagonistic elements.

What has been described highlights the better tribological properties of polycrystalline zirconia, both tetragonal and cubic, concerning the usual glass ceramics that in the portions exposed to wear "example: occlusal boards" increase their abrasive capacity over time, while this is not the case with materials made of polycrystalline zirconia (Fig. 18a).

It is well known how the coefficient of friction/abrasion, with clinical tests on natural dentition opposed/antagonistic to zirconia frameworks or other porcelains, deposes in favour of polycrystalline zirconia both dry and wet by saliva.

About bioinert ceramic materials such as zirconia, what has been described allows the combined use of information from intraoral optical readers and extraoral advanced facial analysis systems to achieve a balance of individual harmonic integration.

Clinical procedures and analog-digital techniques allow the figures' results to be obtained with methods that use what is described by the Lagrange-Dirichlet theorem, which we will analyze. Again within said theorem, a fundamental aspect of these materials is to keep the perturbations "in a known

Vibrations are mechanical oscillations around an equilibrium point. Their unit of measure is the "hertz" which indicates the frequency of periodic oscillations in a single second.

In recent years a different and very advanced technology has been developed, which is based on MEMS sensors. Accelerometers equipped with this technology such as the "fast tracer" are today one of the most important innovations in the field of nanotechnology. And these sensors are already widely used in airbags, electrical appliances, field transducers, cell phones, video game consoles etc.

Fig. 25

- **Rotating machines are divided into various categories (see ISO 2372)**
- In funzione delle frequenze caratteristiche si utilizzano tipicamente ranges di ammissibilità in spostamento (basse frequenze), velocità (medie) ed accelerazione (alte)
- Il confronto con curve limite determina lo stato di funzionamento della macchina (ottimo, buono, ammissibile, tollerabile, ...)
- E' comunque buona norma procedere all'analisi di funzionamento di un sistema così da ricavare criteri di tipo sperimentale

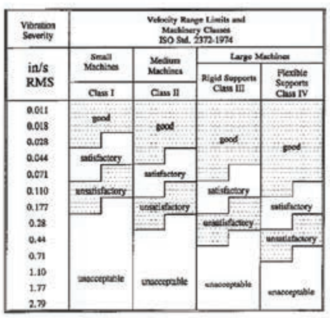

Fig. 26

- **The "overall RMS" level represents the overall vibratory energy in a certain range of frequency**
- $RMS = \sqrt{\frac{1}{T}\int_0^T v(t)^2 dt}$
- **The ratio of average from peak to peak to-peak and rms level depends on the type of signal**
- **Crest factor = peak level / rms level**

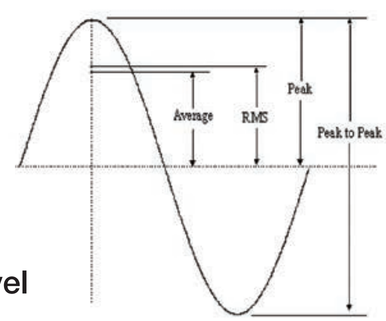

Fig. 27

- **As the rotational speed changes it is possible to measure the level of the corresponding harmonics (orders)**
- **The central frequency of the filters is proportional to the rotation frequency**
- **The simultaneous acquisition of the tachimetric and vibration signalsare essential**

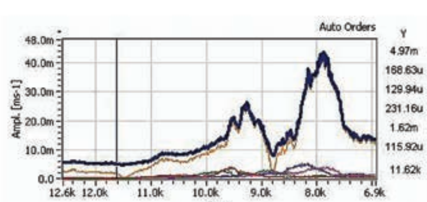

Fig. 28

range" on pain or unpleasantness such as cracks and fractures. The starting point of any CAM processing is appropriately handling the zirconia wafers used by the milling machines, "Millers" (Figs. 19 and 20).

It is known that from these wafers, different dental elements can be extruded by milling, from single teeth to bridges up to entire arches. Such wafers can be milled several times until they are fully utilized. During these processes, we will have wafers with the presence of empty areas and "gaps." Such wafers, unlike their initial state, will dissipate vibrations uncontrollably. To avoid this problem, I have been preparing wafers with appropriate vibration dampers properly called Shock Absorbers (Fig. 21).

Shock Absorbers are devices designed to absorb and dampen shock impulses. They do this by converting the kinetic energy of the Shock into another form of energy (typically heat) that is then dissipated. Most shock absorbers are "a form of dashpot," that is, a damper that resists motion by viscous friction. A damped wave is a wave whose amplitude of oscillation decreases over time, going to zero with an exponential sinusoidal decomposition; it is an oscillating sine wave in which the amplitude of the peak decreases from an initial maximum to zero at an exponential rate.

An adaptive base isolation system includes a heat sink, in our case resinous, designed to minimize the vibration transferred during the CAM milling stages of the wafer. The pictures, better than other words, describe the use of pre-sintered zirconia in appropriate portions, shapes, and positions joined with the help of PMMA acrylic resin. Such structures can fulfill the above-described functions of vibration dissipation, thus accomplishing another important control and verification step within the L & D Theorem.

Vibrations and their measurement

Those who, in addition to the beauty of bioinert ceramic materials, want to evaluate the intrinsic physical/chemical/mechanical characteristics that can lead to success or failure need to know the result of some critical research on the distribution and dissipation of vibrations, i.e., induced mechanical oscillations, which are very different from what occurs in metal-ceramics (Figs. 22 and 23). We can obtain these measurements using piezoelectric vibrometers composed of the transducer, amplifier and indicator, measuring instruments that allow direct readings of vibrations/oscillations with appropriate transducers (elements that convert a physical quantity into an electrical signal) that analyze the non-repetitive physical phenomenon typical of dental and dental technology work such as those induced by rotating instruments.

Clinical analysis systems for Rx, dental-scan, cone- beam and whatever else of use in the clinical setting use STL data that combine well with digitized dental procedures suitable for the analog-digital CAD-CAM stage of prosthetic finalization with metal-free methods and materials (Fig. 24).

The evaluations made so far are "professional," related to dental and dental technician activity aimed at meeting the functional aesthetic needs of the patient who Today increasingly prefer their natural appearance and better integration in the oral cavity non-metallic structures.

In complex structures (See Figure 24), the clinical and technical effort with which they are designed, fabricated, and

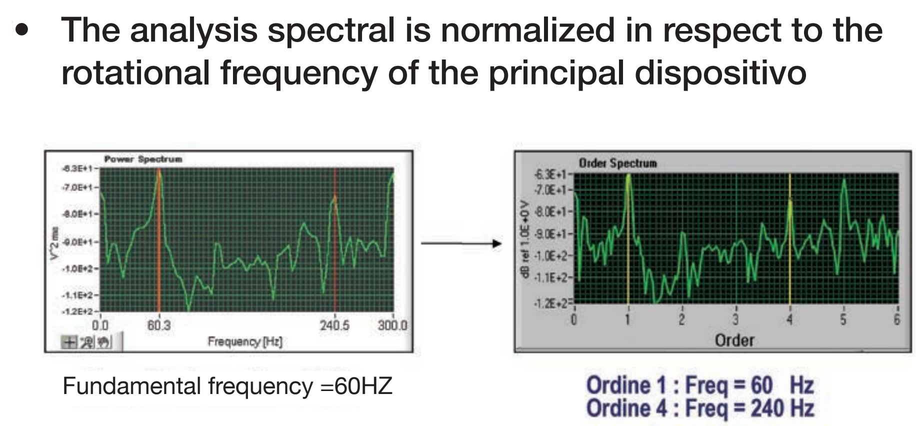

Fig. 29

Fig. 30

Fig. 31

finalized is aimed primarily at obtaining durable aesthetic-functional prosthetic restorations. To achieve this, it is vital to minimize vibrations, i.e., the mechanical oscillations induced to zirconia structures at all its processing stages in the technical and clinical spheres; a particularly delicate moment is the phase preceding the sintering(Figs.24and25). To best comply with zirconia structures, materials must always be supported by materials that dissipate vibration during processing that tend to absorb the induced mechanical oscillations.

Practical processing techniques: initially, for manual handling of zirconia prosthetic devices, I used wadding support (Fig. 22). Today, I use silicone pads (Figs. 10 and 23), a readily available advanced technology with very high vibration-absorbing capacity. The figure shows the milling by hand-free hand milling without the silicone gel heatsink


Fig. 32

and controlled milling using the silicone gel heatsink; note the different amplitude of the waves recorded by the piezoelectric vibrometer transducer. The subsequent post-sintering finishing stages involve rotary cutters that "inevitably" produce the harmful and dangerous phenomenon of vibrations, i.e., induced mechanical oscillations (See photo).

My systematics involves the use, even at this stage, of unique and individual vibration dissipators made of two-component silicone of medium 75/85 Shore hardness, a multi-purpose material used in the laboratory for various applications. The obtained results of dissipation of harmful vibrations are evident when measured with the particular instruments described and are also clearly perceived by the sensitivity of our fingers (Figs. 26 to 29).

With what has been described, we can routinely obtain prosthetic devices of good optical-luminous quality free of structural imperfections. Devices that can exploit their excellent physical-mechanical resistance to abrasion, compressive and flexural strength. Devices that, thanks to the use of 0.3 mm, 0.5 mm, and 1 mm gradual thicknesses adequately designed and fabricated, give the possibility to finalize by a layering of glass-ceramic the zirconia structure.

The physicality of the ZrO2 structure is exploited to ensure the protection of the glass-ceramic during all functional paths, of protrusive, canine guidance, right and left laterality, going to finalize the devices by completing the shapes and layering with specific glass-ceramics with high aesthetic value. Shown are some details of the feldspathic glass-ceramics, made in conjunction with polycrystalline zirconia. The "transillumination through-light test" (Fig. 28) allows us to verify the relationship between the masses of aesthetic veneer and the zirconia substructure, different materials in different portions and anatomies optimally integrated. Furthermore, some "deep" layering arrangements based on specific laws of optical physics allow us to obtain through defined parameters of refraction, reflection and absorption results very similar to natural teeth for natural-looking integration even in complex dento-skeletal structures.

Conclusion

In this monograph, we have tried to emphasize the importance of flanking the necessary artistic-creative knowledge and skills (Fig. 30) with the chemical-physical and mechanical use skills of the materials used, stressing how, at each stage, we must pay attention to structural stresses.

Key steps are milling, finishing and polishing, which must be carried out and controlled with the help of special vibration absorbers. Both in the CAM phase with a special Shock Absorber and the manual handling phase with the use of suitable tools, some standard, made of silicone gel, others individually made with customary laboratory silicone at 75/85 Shore.

What has been described underscores how the human aspect of prosthetic dentistry is inescapable to ultimate success (Figs. 30 to 32). Prosthetic devices are individual, unique and unrepeatable; we have tried to argue how they are made with scientific knowledge and artistic sensitivity, as this is the beauty of being called upon to restore what the patient needs.

Figure 32 shows a patient with outcomes of cheilognatopalatoschisis. Cheilognatopalatoschisis (partial or complete) results from disorders of embryonic development. This laceration may involve only the lip, the maxilla with the lip or the lip, maxilla and palate (rarely only the palate). The causes of this laceration can be endogenous (congenital) or exogenous (e.g., viral infections in pregnancy, medications, vitamin or oxygen deficiencies). We must make a distinction between unilateral and bilateral tears. Treatment of cheilognatopalatoschisis requires, as a rule, the synergistic co-participation of orthodontic-surgical treatment and mostly takes place within specialized facilities (specialized clinics, university clinics). We finalized the complex case in the image in Zirco/Ceramic ZPS ARD.

We will expand the dental cases presented in the first section of this monograph in the second section of this lengthy article. Sd

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