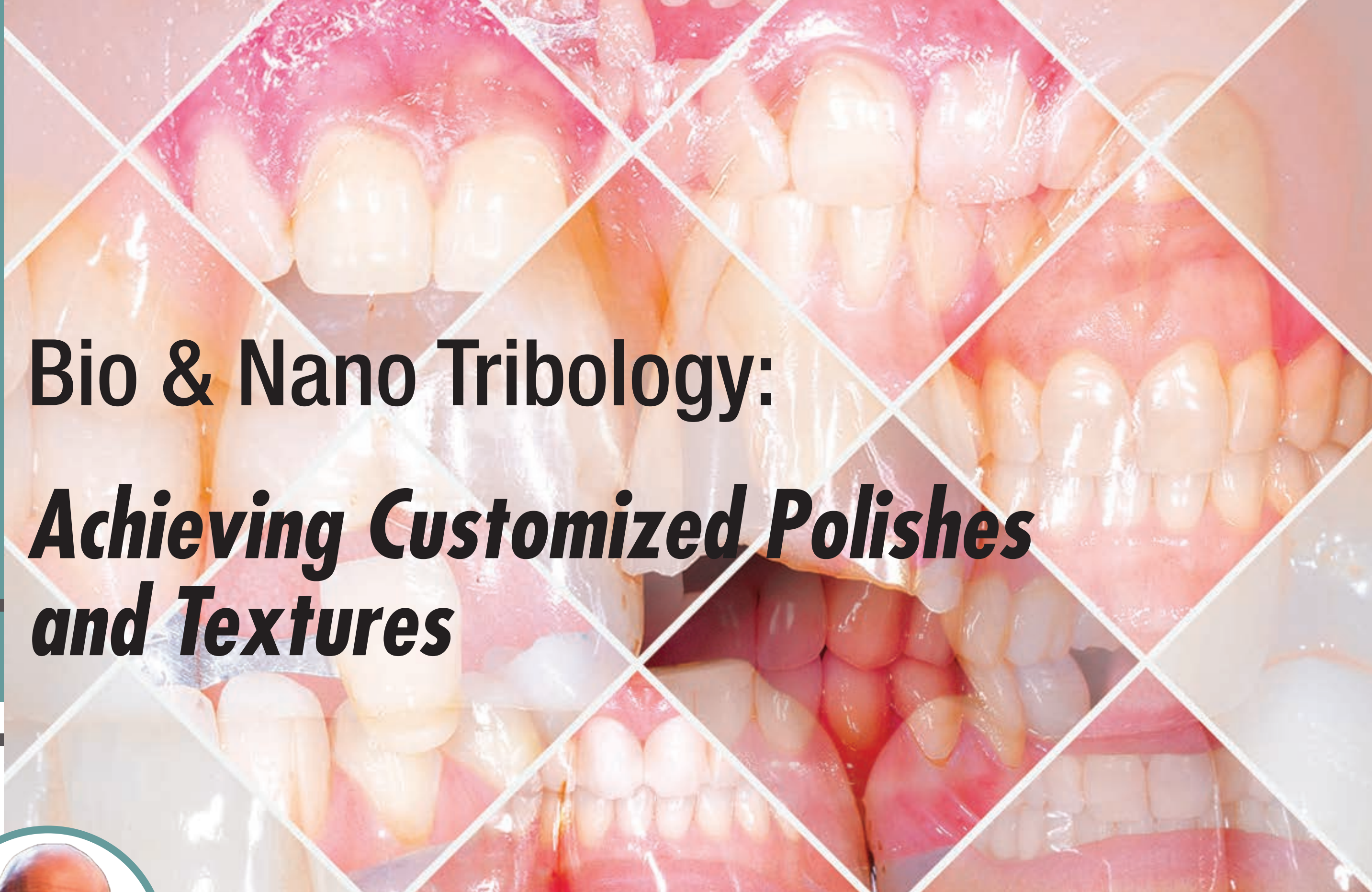

Bio & Nano Tribology:

Achieving Customized Polishes and Textures

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An active member of AIMAD, AIOP, and other prestigious organizations, he has held leadership roles, authored 64 scientific publications, co-authored six textbooks, and owns three international patents. He is a professor at renowned universities in Italy, including Università di Modena e Reggio Emilia and Università "Vita Salute San Raffaele" in Milan. In 2010, he received the Medal of Merit from the President of Italy.

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Presentation

From the beginning, humans have dealt with tribology—the science of friction and wear. Primitive examples include rubbing flint stones or sticks to produce fire, inventing the wheel to reduce friction during transportation, and more.

Tribology plays a crucial role in various applications of prosthetic dentistry but remains relatively unknown.

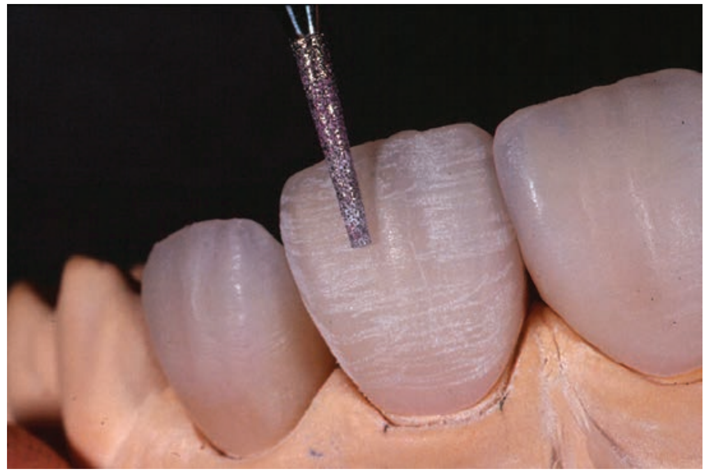
This article aims to provide an insightful overview of the topic, offering practical guidelines for its application in dental prosthetics.

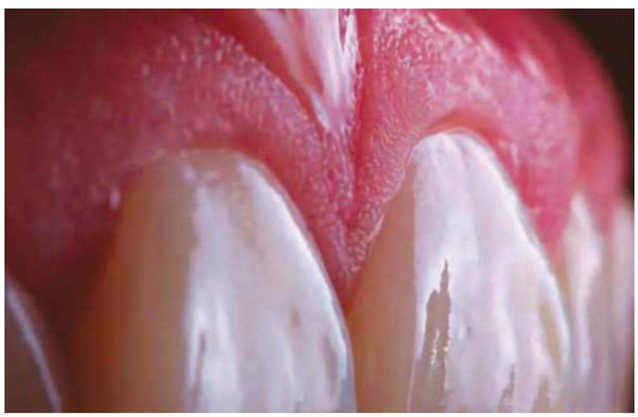
Introduction

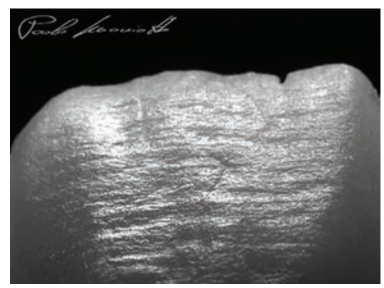
Tribology is the study of friction and wear, examining issues arising from the relative motion between interacting surfaces under load.

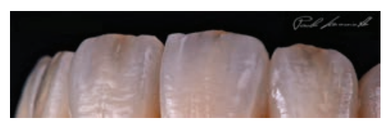
The term originates from the Greek words tribos (friction) and logos (study or science), literally translating to "the science of friction."

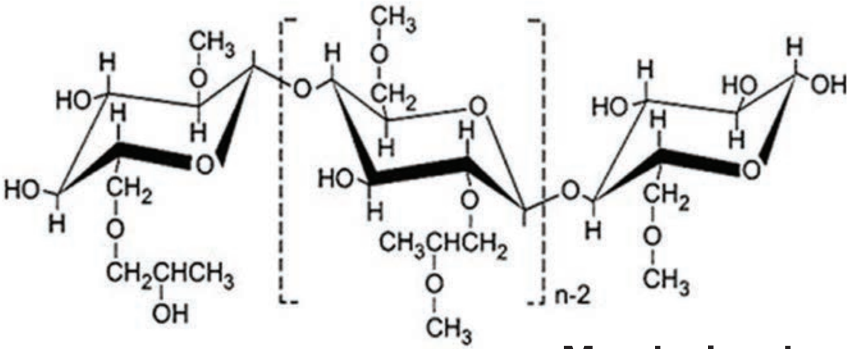
The most accurate definition of tribology is: "The science and technology of interacting surfaces in relative motion, including associated material substances and practices."

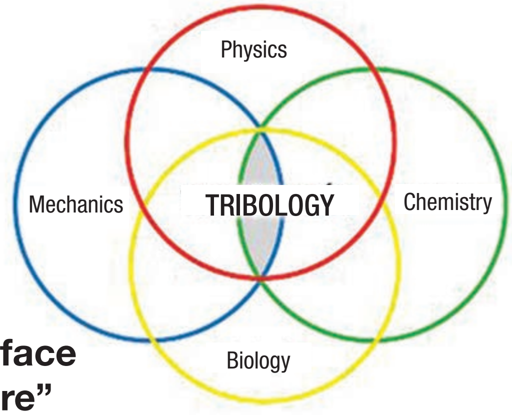












Marginal and surface finishing "Texture" Bio&Nano/Tribology

In dental prosthetics, tribology encompasses studies on physical interactions, materials, and tools such as drills, rotary instruments (burs, felt wheels, rubber polishers), and abrasive pastes of various types and compositions.

Theories of Friction and Wear

In 2016, Ian Hutchings from Cambridge University highlighted that Leonardo da Vinci's notebooks contained observations on friction, still foundational today:

1. Frictional force between two sliding surfaces is proportional to the load acting on them, with a coefficient of 1/4 for clean, smooth surfaces.
2. Friction is independent of the contact area between the surfaces.

Leonardo also provided an additional contribution to the study of friction. By delving into rolling friction, he reached the important conclusion that this type of friction is not connected to sliding but rather to a type of contact that can be seen as a progression of small sequential steps.

The phenomenon of wear was seriously considered at the beginning of the 1900s. Among the first scholars of wear was Ragnar Holm, who in 1946 stated that the rough surfaces of materials come into contact only at their asperities or highest peaks.

The singular term "wear" actually encompasses four main distinct and independent phenomena, all involving the removal of solid material from rubbing surfaces. Thus, instead of simply speaking of "wear," it is useful to recognize the following distinct types of wear:

1. Adhesive wear
2. Abrasive wear
3. Cutting wear
4. Corrosive wear

Subsequently, wear was also subdivided into moderate wear and severe wear, depending on the size of the particles produced, the resistance of the contacts, and the effects observed on the surfaces.

Physics of Tribology: Friction

The term "friction" derives from the Latin atterere (to rub). It describes dissipative/abrasive phenomena producing heat and resisting relative motion between two surfaces.

There are two main types of friction:

1. Static Friction - Between stationary surfaces.
2. Dynamic Friction - Between moving surfaces.

A particular type of dynamic friction is rolling friction. In prosthetic dentistry, rotary burs are used. This involves a particular type of friction, in which the phenomenon of sliding—typical of dynamic friction—does not occur. However, there is still a counterforce (the operator's moving hand Odt. and/or Dr.) opposing the rotating motion of the bur, excluding static friction. This type of friction is defined as rolling friction and is also present in Newton's third law (the worked material has intrinsic elasticity).

Let us now examine in detail what happens to a bur rotating on a dental surface.

Initially, the bur is stationary, and the forces acting on it are gravitational force $m\vec{g}$ and $N\vec{r}$, the operator's hand force.

What happens in detail between the rotating bur and the contact area on the dental element, where the reaction forces of the dental element act on the rotating bur, causes imperceptible abrasions to the dental element through the bur's transition from one point/zone to the next.

During the compression phase, the dental element opposes the bur's motion, while in the decompression phase, it contributes positively to the motion. Rolling friction, therefore, depends on the minor abrasions sustained by the supporting dental element, the rotation of the bur, and can be expressed as:

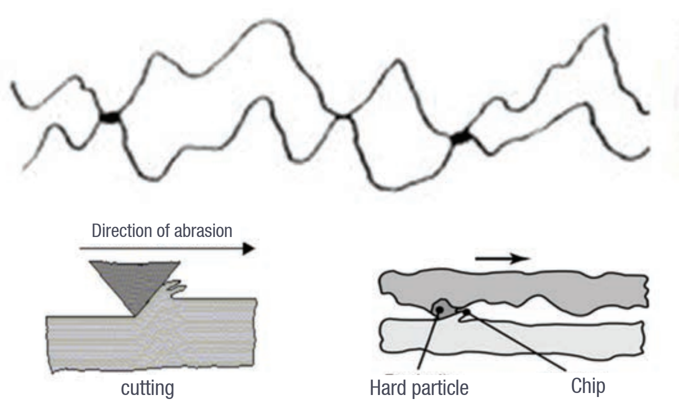
$$F_v = b \cdot N$$

where b can be expressed in relation to the coefficient of sliding friction μ: $b = r\mu/v$

with r being the radius of the bur.

Diagram of the forces opposing compression

Given the complexity of phenomena related to friction, it is essential to understand the contribution made by the properties of the materials and surfaces involved. If we examine a ceramic element and analyze its surfaces under a microscope, previously ground with a bur (e.g., mounted or diamond point, not polished), we observe undulations and irregularities similar to a microscopic mountain range, called asperities (see figure below).

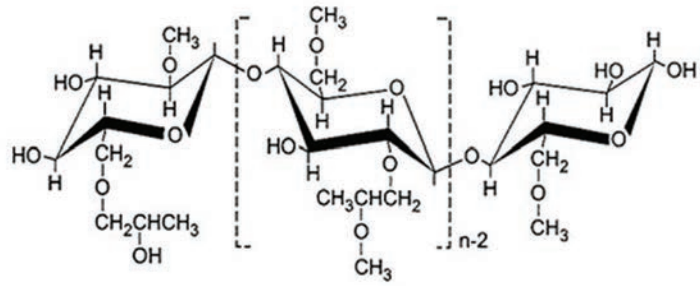


The origin of the friction generated by the bur on the dental element is actually a contact between asperities with energy dissipation. This is primarily due to the abrasions that the asperities undergo as a result of the load and the translational/rotational movement of the bur and abrasive pastes.

Tribological Applications

Among the tribological applications described earlier, the ones of interest in dental prosthetics are:

1. **Nanotribology:** Focuses on tribological phenomena occurring at nanometric scales.
2. **Biotribology:** Concerns tribological phenomena within biological systems related to the human body.



Nanotribology

In the 1980s, with the introduction of new measuring devices capable of investigating at microscopic and nanoscopic scales, as well as the increasing computing power, it became possible to study the phenomenology of friction at a nanometric micro-scale. This study primarily had two objectives: Explain the fundamental laws of abrasive friction and Define the nanoscopic properties of friction.

Biotribology

In the medical field, tribology plays a fundamental role, from the wear and friction of everyday contact lenses to common orthopedic and dental prostheses. Biotribology mainly addresses the wear of prostheses and biomedical devices. A collateral application of the aforementioned studies enables targeted management of the surface finishing phases of dental prostheses, which occurs through a precise movement called rototranslational motion, a topic we will describe below.

Rototranslational Motion in the Use of Burs, Brushes, and Rotating Felt Wheels

The movement employed with tools such as burs, brushes, and felt wheels for the usual finishing phases of dental prosthetic devices is defined as rototranslation. The finishing phases consist of two steps:

First phase: Using burs to achieve the correct definition of the volumes and shapes of each individual prosthetic dental element.

Second phase: Using brushes, felt wheels (Fig. 1), and specific abrasive pastes, including diamond pastes, to achieve the ideal level of finishing, or texture.

For proper movement management, both phases must be considered simultaneously: the first involves rotational motion, and the second involves dynamics, where the first imparts direction, and the second imparts force.

The finishing of each prosthetic dental element, especially if made of ceramic material, is considered an operator-dependent procedure. This is because the tools, motion direction, and intensity of applied force are modulated based on the goal to be achieved and the operator's "sensitivity."

Specifically for the dental technician profession, the industry provides a range of specific tools (burs, brushes, felts) in various shapes and sizes, which can be paired with specific abrasive pastes in order to achieve the ideal finishing grade for the best bio-morpho-functional integration, a fundamental requirement for good integration in the oral cavity, a precursor to sufficient long-term clinical success.

It is known that every dental prosthetic realization is individual under the aspects of shape, color, and function. The acquired skills allow, with the help of tools and materials, to achieve the objectives outlined in the treatment plan with good precision. However, it is also known that there are aspects that go beyond "pure technique" and delve into "purely aesthetic" aspects. There is no single definition of aesthetics. For us, the adopted definition, the result of continuous updating through participation in qualified courses and conferences, is: "AESTHETICS IS AN INTERACTION OF CULTURAL AND SOCIO-ECONOMIC ASPECTS." For these reasons, aesthetic perception is in continuous individual evolution.

These premises led to the personal need to improve the specific aspect related to the individuality of the satin/gloss of the aesthetic surfaces of prosthetic rehabilitations.

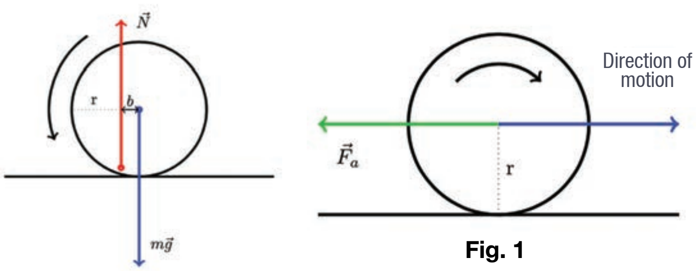


Fig. 1

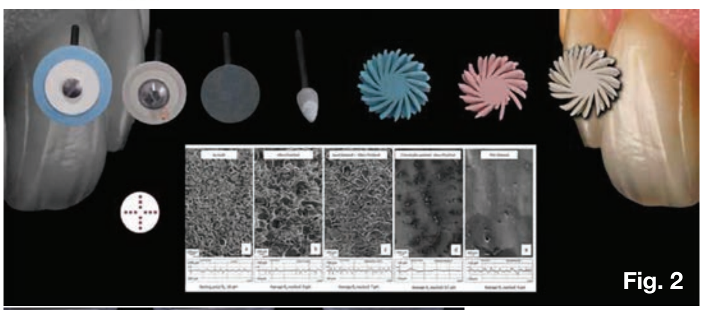
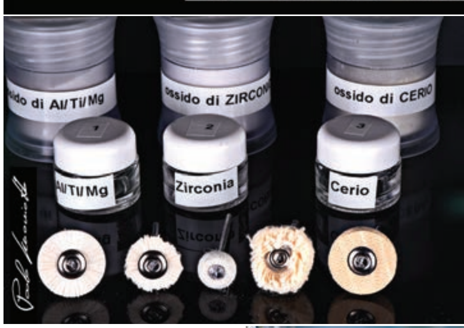


Fig. 2



To this end, we tested many good products provided by sector companies without ever reaching full satisfaction, as pre-packaged "pastes and/or sticks" did not allow us to modulate the necessary individuality that we assumed we could achieve. This is why, for the past ten years, we have sought alternative routes that, with the experience gradually acquired, allowed us to also satisfy the particularly individual aspect related to the modulated brilliance of the individual teeth present in the arch.

B.N.T Technique (Bio-Nano-Tribology) by PaSma

In the first part of the article, we tried to describe the basics of understanding the concept of TRIBOLOGY. Now, we will delve into the specifics of what personal research has allowed us to achieve in order to improve the perceived quality during the aesthetic finishing phases of our dental prostheses.

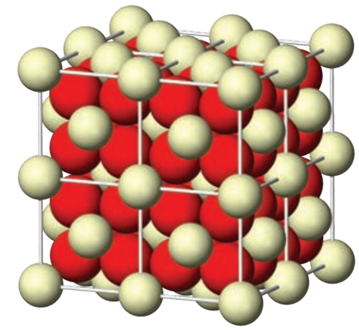
As shown in Figure 2, the goal is to achieve, in sequential phases, the natural appearance of the prosthetic elements, not only by using rotating tools, pastes, and sticks provided by the industry but also by creating individual pastes with variable densities, modifiable by the operator. Over time, various powder materials bound with solvents to make them pasty were tested. We used powders of various types commonly found in dental laboratories (plasters, resins, etc.), as well as liquids (alcohol, soaps, sidol, etc.), initially with unsatisfactory results compared to the usual industrial diamond pastes.

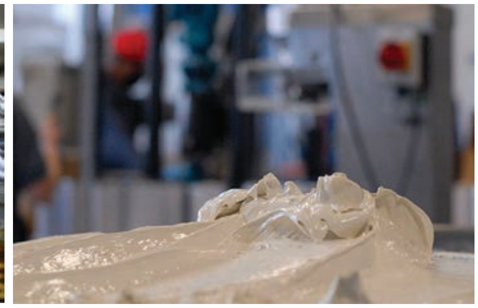
By focusing more specifically on the lubrication vectors, attention was given to the use of synthetic fluids (sidol), natural oils (seed and olive oils), and more consistent pastes (vaseline paste) to mix the abrasive powders with variable granulometry (metal oxides) and the aforementioned lubrication vectors.

After testing the use of some abrasive powders made from marble mixed with sidol, we obtained decent results on composite resins but not on dental ceramics. We then moved on to using Al/Ti/Mg oxide powders, ZrO_2 zirconia, and CeO_2 cerium oxide or cerium dioxide, known as CERIA, which has a color ranging from white to pale yellow and is odorless. This product is used for abrasive operations and polishing glass materials or porcelains.

After some tests, we verified the excellent abrasive capabilities of the three pastes obtained as follows:

1. **PASTE 1 -** First pass: Paste made with Al/Ti/Mg oxide powder (extra fine lipari) mixed with olive oil in a 7/3 base ratio (modulable as needed).
2. **PASTE 2 -** Second pass: Paste made with Zirconia ZrO_2 oxide powder mixed with olive oil in an 8/2 base ratio (modulable as needed).
3. **PASTE 3 -** Third pass: Paste made with CeO_2 cerium oxide powder mixed with vaseline paste in a 6/4 base ratio (modulable as needed).





For finishing ceramic dental structures, sequential steps are followed using the three pastes described above. The rotary-translational movement of the brush/felt should occur with a gradual rotational speed from 3,000 rpm to 10,000 rpm, with a pressure of 250/350 grams per cm (the pressure of only the forearm/hand weight).

Presentation of Clinical Cases using the B.N.T Technique

As masterfully described in "Principles of Aesthetics" by C. Rufenacht (1992) and Koidou VP, Chatzopoulos GS, Rosenstiel SF. (Quantification of facial and smile aesthetics. J Prosthet Dent. 2018 Feb;119(2):270-277), among the determining aspects of aesthetic success in the anterior sextant, the finishing of the margin and surface, called TEXTURE, is a primary factor. The morpho/functional/metameric integration of the prosthetic device is achieved through the correct management of every constructive factor aimed at mimicking the naturalness of the rehabilitated dentition.

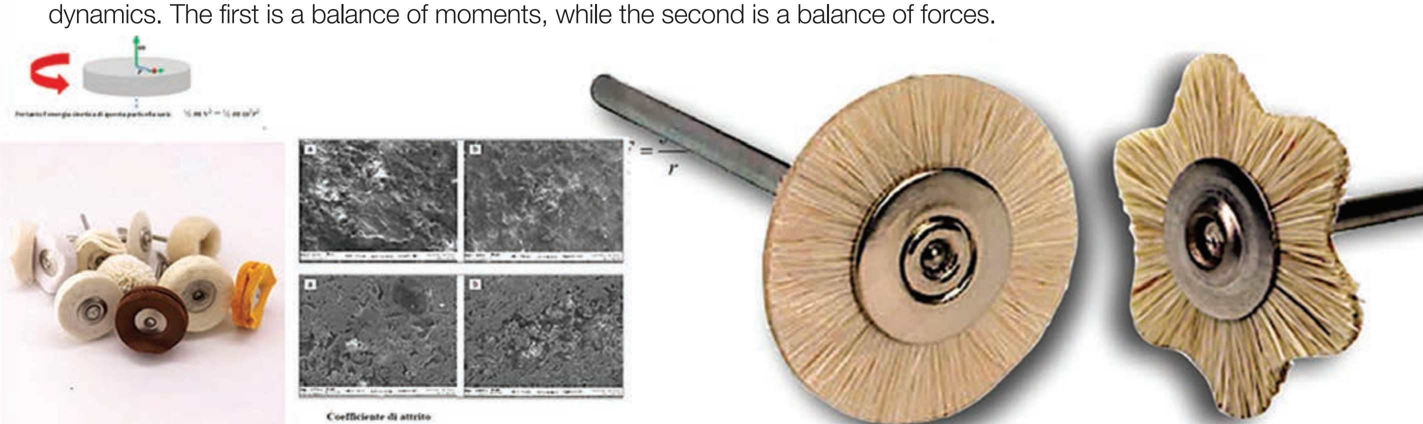
(Presentation and description of some clinical cases by Dr. Tommaso Tura)

In order to achieve satisfactory aesthetic integration of the dental elements, clinical knowledge of the material used is essential, whether it is disilicate, multi-layer zirconia, or cut-back zirconia. Special attention should also be given to the type and method of cementation used. The final result requires repeated experimentation and experience, as it conditions the final metameric effect achievable.

The various materials proposed have different surface finishing properties, and the final result is also conditioned by the color of the underlying stump, the available vestibular and occlusal thickness, and the conditions of incident light.

The clinical examples provided here refer to different types of materials, chosen based on the required clinical conditions: therefore, it is clear that the clinician must also have knowledge of the tribological properties of the materials used in prosthetic dentistry.

In the case of rotational-translation motion, such as that of a cylindrical roller on a horizontal frictionless plane, it is necessary to simultaneously consider the fundamental equation of rotational motion along with Newton's second law of dynamics. The first is a balance of moments, while the second is a balance of forces.













A2


B2

The need to be aware of both moderate and severe abrasive wear characteristics puts many opinions in comparison regarding the appropriateness of using dental materials that are widely used today.

Partially stratified lithium disilicate with feldspathic ceramic allows, thanks to careful processing of its surface, an appearance similar to the adjacent teeth.

The need to restore physiological functional guides, previously compromised by parafunctions with altered occlusal dynamics, recommended the use of "additions" placed in areas with greater wear.

After a study with individual articulator values, guide inserts in lithium disilicate were made. In this case, the finishing of the surface texture required particular attention, and the use of cements and cementation techniques played a decisive role.

The sensitivity of the operators allowed for adequate and long-lasting bio-morpho-functional integration, counteracting the dynamic friction forces present.

In this typical prosthetic case, the correction of the shape and color of the upper anterior dental elements allows for a significant change in the smile and lips.

Unlike the previous situations, the tetragonal zirconia structure with superficial feldspathic ceramic firing, combined with the proposed finishing technique, allows for a new natural appearance of the dental elements.

The following briefly describes the main phases of realization: color taking, temporaries, zirconia structure, final firing.

Determining the color of the stumps themselves, before and after trimming, provides the first indications to the dental laboratory for the base structure.

The appropriate color of the tetragonal zirconia facilitates the possibility of satisfactory stratification.

The surface texture performed with the previously described technique provides the desired match to the existing dental elements and the creation of an aesthetically integrated product.

Conclusions

The dental rehabilitation practice today must consider multiple factors that condition the aesthetic-functional result for the patient. Knowledge of the limits and possibilities of polishing and texture techniques performed by the dental laboratory is currently of considerable importance for solving clinical cases with high aesthetic value.

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