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ANALYSIS OF NEW DENTAL MATERIALS

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Abstract: *Technological advancements in the field of dentistry have led to a various number of new classes of restorative materials. There is a great need and demand to analyze these materials for their optical, thermal, electric, and mechanical properties. Furthermore, the biocompatibility, and material compatibility of each material should be investigated as to the effects that these materials have on each other and on opposing natural dentition in the oral cavity during normal function and parafunction. Dental materials should be selected to minimize stresses and should be designed to distribute forces as much as possible while maximizing biocompatibility and aesthetics.*
Keywords: *dental implants, composite resin, metal-ceramic restorations, screw mechanics*

1. INTRODUCTION

In recent years there have been numerous new dental materials on the market due to the technological advancements associated with CAD/CAM design and chair-side milling. New dental materials must be analyzed based on their chemical composition and molecular structure in order to ensure a compatibility with the patients' natural dentition, and just as importantly any existing dental restorations. Natural teeth and any type of dental restoration exhibit specific and unique mechanical, physical, thermal, elastic, chemical and biological properties. These materials all react differently to applied stresses in the oral cavity and the effects of having incompatible materials opposing each other can lead to the catastrophic failure of a restoration or an opposing natural tooth. The prolonged exposure of dental restorative materials to occlusal and excursive forces should be investigated as well as their interactions with other opposing restorative materials.
There have been many advances in the field of dentistry and in dental materials over the years. The change from cast metal restorations to metal-ceramic restorations occurred after issues with the modulus of elasticity (Young's modulus) and coefficient of thermal expansion between the base alloy and veneering ceramics where resolved. The next leap forward came in the 1980's-90's with the widespread use of dental resin composites and multiple generations of improved resin composites to follow after the implementation of fortifying fillers, hybrid blends etc. This brings us to the current advancement of using all-ceramic restorations that can be milled chair-side from a composite-resin, lithium disilicate, zirconia or other type of ceramic material. These materials are available in block form either in a monochromatic or polychromatic shade (color) and depending on the material can be in the final form or may require final sintering in a material specific oven to obtain the final restoration after milling. This is also an important distinction among the materials as some materials exhibit annealing properties as they undergo a structural transformation in the sintering oven post milling. It is also important to note that the manufacture recommended material thickness of each material is specific to that material but usually in a range between 1.5mm - 2.0 mm. Another important factor to consider is the type of milling machine that is used, the grit of the burs, lubrication and the speed of the milling process. All of these factors can influence the amount surface cracks present on the surface of the restoration. These restorations are usually polished and glazed on the external surface but there is no protocol given for polishing or glazing the internal surface of these restoration as it is thought that any internal voids will be filled and supported by the cements and/or bonding adhesive agents.

2. THEORETICAL AND EXPERIMENAL ASPECTS

Dental materials have undergone tremendous change over the last few decades. The transition has gone from full-gold crowns and amalgam fillings to All-Ceramic restorations that look just like the adjacent natural teeth. The aesthetics of current dental materials is vastly superior to past materials, today All-Ceramic crowns can be pressed to knife-edge precision eliminating the dark metal show-through on older Metal-Ceramic crowns.

Materials used to contain Hg, Ni, Sn currently materials are composed of medically pure Ti. Material biocompatibility is a key factor in the success of a restoration current restorative materials do not contain toxic or allergy causing material. Dentistry has moved away from the use of Amalgam fillings which contained mercury also there has been a shift away from certain metals like Tin, Nickle and others that have been shown to cause allergic reactions in patients. The cost of certain metals has also become an issue as the cost of a crown or three-unit bridge made of a high noble alloy has a large composition of gold, platinum, palladium and other noble alloys that can raise the cost of the restoration considerably.

In the past a patient requiring a full contour crown would need to come in for the preparation procedure, a mold of the prepared tooth would be made, a temporary crown would be placed over the prepared tooth and the mold of the prepared tooth would be sent to a dental laboratory for the final restoration to be fabricated. The process would take about 1-2 weeks for the dentist to receive the final restoration. Today the prepared tooth can be scanned chair-side and the restoration is milled in the dental office in about 15 min. and the final restoration is then polished and sintered and delivered the same day. What was a 1-2-week turnaround time has now been cut down to 1-2 hours. The most important part is that the patient does not have to take more time off work to come back for a second appointment, and the dentist and the patient don't have to deal with temporary crowns that break, come off or get lost.

Last but not least is the ability to use osseo-integrated dental implants to replace a single missing tooth or several implants to replace a full arch of missing or decayed teeth. Osseo-integrated dental implants have become a game changer in today's society. The osseo-integrated dental implant is a post that is screwed into the bone under high torque and at low speed. There are many different types of dental implants most are made of medically pure titanium; some are now being made of Zirconia. The length, diameter, thread size, surface coating, collar characteristics and connection type all vary from manufacturer to manufacturer. Once the implant is placed into the bone there is usually a healing period that allows for integration of the implant. After the implant is deemed integrated a prosthetic crown is placed onto the implant either with an internal screw or by placing and abutment onto the implant and cementing a crown on top of the abutment. When using multiple implants more complex prostheses can be fabricated to replace even a full arch dentition. The materials that can be used for such prostheses can range from acrylic, acrylic with metal, metal-ceramic, all-ceramic, zirconia and zirconia with layered ceramic. The type of material used for each restoration or prosthesis has different physical, mechanical, optical properties and different costs!

With the addition of osseo-integrated implants to the dental armamentarium there is also the addition of a new application of physics with regards to implant components such as implant screws and implant-implant abutment connections. Implant screws are utilized to retain the implant crown or an implant abutment to the implant. The crown or abutment is retained by a screw that is inserted occlusally through the crown or abutment and engages the internal section of the implant resulting in a clamping force that retains the prosthesis. The length, diameter, material composition, surface coating and thread area of the screws are all extremely important to the amount of pre-load that is generated in the screw. These factors are also taken into account in determining the final manufacturers recommended torque for the implant restoration.

With hundreds of different implant companies globally that all have different types of implants with different internal and/or external connection designs there is what seems to be countless combinations of screw and implant connection designs. This has led to thousands of off-brand components that can found on the market leading to a dire need to examine the compatibility of all component products and evaluate their performance when exposed to: tensile stress, shear stress, elastic deformation, plastic deformation, friction. By using these implant components without understanding basic screw mechanics and appreciating the physical properties of these components and their reactions under tensile and shear stresses this will result in mechanical system damage to the screw (loosening or fracture) or to the implant (connection damage or fracture).

3. MECHANICAL PROPERTIES

When selecting a dental material for a specific restoration or dental prosthesis it is imperative to understand and predict a materials behavior under load or in function. Dental materials exhibit different values when exposed to quantities of force. Under load dental materials have different values for stress, strain, strength, hardness, friction and wear. In general, the stability of a solid under applied load is determined by the nature and strength of atomic binding forces.One of the most important applications of physics in dentistry is the study of forces applied to teeth and dental restorations. It is necessary to determine the area over and direction in which that force acts. In general, natural teeth do not touch each other while masticating. They get very very close and proprioceptive fibers attached to each tooth send signals back to the brain and muscles of mastication to stop closing and open, therefore protecting the teeth from contact. With that being said teeth touch when swallowing and in parafunction (clenching, grinding and bruxing). Parafunctional habits that mostly occur at night while sleeping is the main culprit in accelerated tooth wear. Clenching is generally considered a vertical application of force while grinding or bruxism is considered a lateral or elliptical motion. In situations where a new restoration or dental prosthesis is placed in the oral cavity and that restoration is slightly higher than the adjacent teeth in function then that area over which those forces are applied is extremely small (the stresses developed are equivalent to 400-600 Mpa). The occlusal surface of a bridge under vertical load, is subject to areas of compression and tension, whereas, the gingival portion of the pontic is under tensile stress. The soldered joints however, are under both tensile and shear stress. The importance of strain in dentistry is that a restorative material, such as a clasp or orthodontic wire, can withstand a large amount of strain before failure. These materials can be bent and unbent multiple times with less of a chance of fracturing.

The testing of many materials necessitates loads of 2,200 N or more and the measurement of deformations of 0.02 mm or less. A typical machine that permits testing in tension, compression or shear shown in Figure 1.

Figure 1: Walter+bai ag 50 kN Multipurpose Servohydraulic Universal Testing Machine

In the figure a stainless-steel rod is clamped between a vise, and the tensile properties are measured by pulling the specimen. The load is measured electronically with a strain-gage transducer and recorded on the vertical axis of a strip-chart recorder. The deformation is measured with an extensometer clamped over a given length of the sample, and is recorded on the horizontal axis of the recorder.

In the case of metallic materials, due to various large local tensions that may occur, the materials must possess the following properties:

- High hardness, a high homogeneity of hardness values, avoiding the agglomerations of hard particles.
- Dimensional stability over time.
- High tenacity, compatible with high hardness values.
- High elastic limit, (modulus of elasticity) so that plastic distortions remain within reduced limits. As alloys or amalgamations elements such as molybdenum, tungsten, chromium, vanadium, titanium, which favor maintaining hardness.

4. CONCLUSION

It is clear that the properties of stiffness, strength, and ductility are independent, and materials may exhibit various combinations of these three properties.
Any dental material that is permanently deformed in service, due to functional forces, is usually a functional failure. A prosthesis can be permanently deformed if stresses equal to or greater than the yield strength, and greater than the elastic limit develop in the structure. Parafunctional habits, bruxing, clenching, grinding and other excursive forces can generate extremely high forces on a restoration. Restorations exposed to higher forces than intended will result in deformation or fracture/ failure.
Compressive strength is important in many restorative dental materials and accessory items used in the field of Dentistry. This property is particularly important in the process of mastication. There can be a great variation of forces during function due to the type of bolus (the object between opposing tooth surfaces). The consistency and hardness of the bolus can vary from high hardness like chewing an ice cube, or a hard toffee, to chewing a raw carrot or am apple. Then there are foods like caramels or taffy that or firm and can be compressed but expand laterally as they are compressed causing tensile and shear forces.
The transverse strength test is especially useful in comparing acrylic materials such as those used in denture bases. In this test a force is applied to a denture base as in mastication.
Many dental restorations are permanently deformed during fabrication. Some examples are the adjustment of removeable partial denture clasps and the shaping of orthodontic appliances.
Another important mode of load is torsion or twisting. Dynamic methods including a forced oscillation technique, used for determining dynamic modulus, and a torsion pendulum, used for impact testing, are recommended to study the viscoelastic materials such as dental polymers. Ultrasonic techniques are important to determine elastic constants of viscoelastic materials such as dental amalgams and resin composites. Most importantly, wear can produce biologically active particles, which can excite an inflammatory response. The wear process can also produce shape changes that can affect function. Corrosive wear is secondary to physical removal of a protective layer and is therefore related to the chemical activity of the wear surfaces. The presence of a lubricating film, such as saliva, separates surfaces during relative motion and reduce frictional forces and wear.
The mechanical properties of dental restoration materials must be able to withstand the stresses and strains caused by the repetitive forces of mastication. The design of dental restorations is particularly important to the selection of the best material for the restoration. Restorations and appliances should be designed so that the resulting forces of mastication are distributed as uniformly as possible. Also, sharp line angles, nonuniform areas, notched, scratched, or pitted surfaces should be avoided to minimize stress concentrations.
The physical properties of the oral restorations must adequately withstand the stresses of mastication. Several means may be used to ensure proper strength of a restoration.
In summary, three interrelated factors are important in the long-term function of dental restorative materials:

- Material selection
- Restoration geometry (to minimize stress concentrations)
- Restoration design (to distribute stresses as uniformly as possible).

REFERENCES

[1] Bolfa T., Neamtu T., Cercetari privind capacitatea de deformare plastica in corelare cu parametrii macrostructurali, Contract de cercetare nr.89/85.
[2] Robert G Craig, Restorative Dental Materials, Mosby Inc., St. Louis, 1997.
[3] Dimitriu St., Mecanica ruperii, Brasov, 2002.
[4] Bolfa T., Rezistenta materialelor, Ed. Lux Libris, Brasov, 2000.