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Spark erosion – technology to achieve passivation and correct inaccuracies of conventional prosthetic techniques: A review

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Abstract
Modern precision laboratory procedures have a profound edge over traditional laboratory procedures in fabricating more precise restorations. Spark erosion, also known as electric discharge machining (EDM) is a process by which, a metal is precisely contoured into a desired shape by erosion, using accurately controlled electric discharge through two conductive objects immersed in a liquid medium. This technology is indeed a new and improved face of Prosthodontics and Implant dentistry.

Keywords: spark erosion, passive fit, electric discharge machining

Introduction

Passive fit limits stresses induced by prostheses within physiologic limits. This implies that the fit of the prosthesis should be such that, the tooth or bone should be able to adapt or remodel to the stimuli. In implant prostheses, there is a lack of resiliency at the bone - implant interface. Only 0-5μm of horizontal movement is possible in implants as compared to 8-28μm at the bone-root interface in natural teeth. A non-passive fit transmits undue tensile, compressive and shear stresses to the implant and bone. This is detrimental to long-term maintenance of osseo-integration and can cause crestal bone loss with possibility of screw loosening, pain, soft tissue irritation, implant fracture and prostheses fracture. Factors causing non-passivity include, errors in impressions and impression techniques, elastic deformation of impression materials, stone or investment material expansion, wax distortion, casting defects, soldering inaccuracies, non parallelism of abutments or implants and stresses induced on metal frame works during heat treatment of porcelain. Therefore, passive fit ideally in the range of 10μm is essential for preventing biologic and technical failures of implants and fixed partial dentures. This can be easily achieved by the spark erosion process.

Spark erosion can achieve passive fit of metal sub/super structures and porcelain veneered frameworks. Swivel latch attachments, precision attachments, friction pins, titanium copings for Procera All-Titan system and telescopic crowns can also be fabricated with this technology. Spark erosion surface treatment for better metal-resin bonding is another important application being investigated.

Mechanics of spark erosion

In a spark erosion machining unit, an electrode to work piece relationship is maintained in a liquid medium (di-electric fluid). The electrode (anode) is usually made of graphite, copper, tungsten or zinc and is shaped into the negative form of the desired shape by CAD/CAM or milling. The work piece (cathode) is the metal which is to be shaped into the desired form. A space is maintained between the electrode and work piece throughout the machining process which is known as the cutting gap [a]. The electrode moves towards and away from the work piece assisted by a hydraulic ram c. The di-electric fluid functions as a conductor and coolant during the procedure. This whole unit has a power source that maintains a direct current. The power level selection is dictated by alloy properties used, size of object and amount of erosion required. When the cutting gap is sufficiently small, the fluid ionizes allowing electric discharges to occur. These electric discharges occur at regular intervals and such cycles takes place about 250,000 times a second.

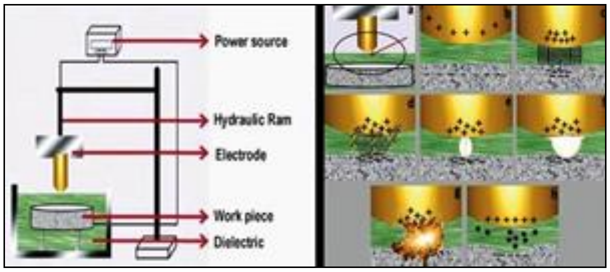

Fig 1: Spark Erosion Machining Unit

As the voltage increases, the hydraulic ram brings the electrode nearer to the work piece. [b]. with increasing voltage, the di-electric fluid breaks down into ionized particles and an ionization channel is established [c]. When sufficient

ionized particles have accumulated to overcome the insulating effect of di-electric fluid, a current is established. [d]. The subsequent build-up of heat results in a vapor cloud formation [e] which gradually expands. When voltage at the cutting gap exceeds the reference voltage, the power gets cut off.
This drastically reduces the temperature at the cutting gap, triggering a collapse of the vapor bubble and generates a high-energy spark of temperature ranging from 8000-12,000 º C [g]. The sudden energy produced causes vaporization of the work piece. The eroded particles [h] are flushed away by introduction of fresh di-electric fluid. When the voltage at the cutting gap falls below the reference voltage at the power source, the cycle repeats itself as the power source is activated automatically.

Procedure for achieving passive fit of implant super-structures

Gunter Rubeling introduced the SAE Secotec Spark Erosion technique to implant dentistry in the early nineties. This system is compatible with most implant systems. It consists of implant analogue sleeves, implant analogues (depending on the implant system used), copper implant electrodes that are identical to the implants used, plastic cylinders for waxing, insertion screws, torque wrench and short and long screws for the laboratory phase.
Impressions are made after the second healing stage. Implant body analogues are screwed into implant analogue sleeves and secured to the impressions. The sleeves are connected with a copper braid to ensure conductivity during the process. The impression is then poured in resin-reinforced extra-hard die stone after blocking out the analogues with soft tissue model material. Conventional procedures are followed till casting and finishing of the sub-structure is completed.
The pictures given below explains the procedures in detail:

Fig 2: Individual tray holding the impression with impression copings.

Fig 3: The lab implant replicas of matching implant system are attached to model shells and then screwed to impression copings.

Fig 4: An elastic die acrylic is poured.

Fig 5: A wax barrier is created and entire area is slightly dusted with silver powder to insulate against epoxy resin.

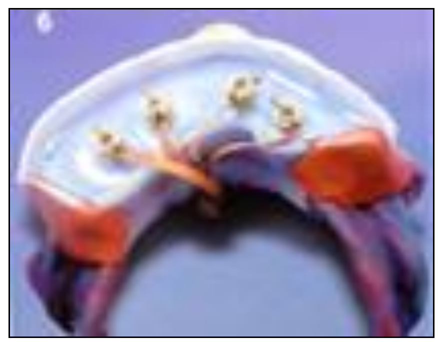

Fig 6: A partial pour is made with low contracting -0.03mm –epoxy resin.

Fig 7: After all the excess wax is removed the remaining pour is completed in type IV die stone.

Sheffield test is carried out before machining to determine passivity. In order to perform this test, the metal sub-structure should be inserted over the supporting implants or abutments. Then the most distal retaining screw should be tightened and the rest of the retaining screws should be kept out. If a gap appears between the remaining supporting abutments and the metal sub-structure, it indicates that the metal framework does not fit passively

Fig 8: Sheffield test before machining showing non passive fit.

Fig 9: The cast with the implant analogues is placed horizontally in the spark erosion unit.

The work piece, is attached to the cradle of the machine with pattern resin. The framework and the cast are connected to the power source by a copper braid.

Fig 10: The hydraulic ram lifts the framework from the model.

Fig 11: Copper electrodes, identical to the implant analogues are used to replace them.

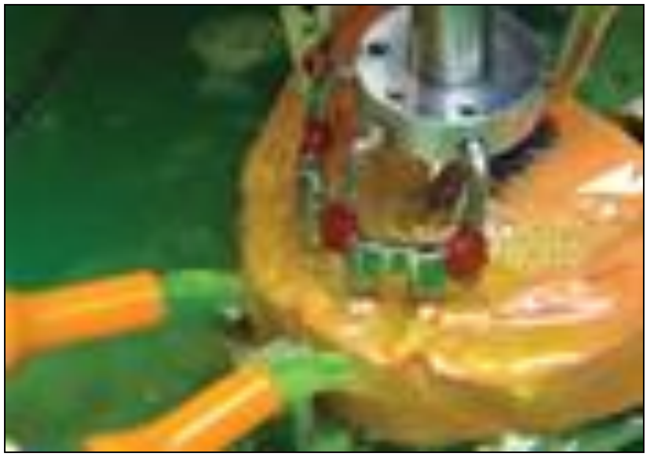

Fig 12: The di-electric fluid is introduced after the cutting gap is set in the unit.

Then, the cradle moves the sub-structure onto the copper electrode and the erosion process is initiated. This takes place at the area where the sub-structure fits onto the implant abutment. The copper electrodes erode rapidly and need to be replaced during the process. The finished sub-structure will exhibit a passive fit.

The Sheffield test, when repeated after machining, shows no gap between the metal sub-structure and abutments.

Fig 13: A passive fit at the abutment-framework interface.

The cast super-structure on which porcelain is to be veneered is initially eroded at the implant abutment -super-structure interface as mentioned earlier. Once spark erosion has resulted in a passively fitting metal super-structure, porcelain is fired to achieve the desired contours. Compressive stresses induced in the framework by firing of porcelain can be relieved by subjecting the finished prosthesis to another round of spark erosion machining, at a low voltage.

Advantages OF SPARK EROSION
1. Passive fit of restorations is achieved.
2. Complex 3-dimensional structures can be shaped regardless of metal hardness since it is a thermal process.
3. An extremely thin work piece can be machined without distortion as no mechanical forces are created.
4. There is decreased stress on the work piece due to the cooling action of the di-electric fluid.
5. There is decreased oxidation of metals during the procedure (especially useful in titanium to porcelain bonding).
6. It is rapid, efficient and accurate (within 0.0254 mm).
7. Frameworks with porcelain can be spark eroded without any stress on the porcelain due to the cooling action of the di-electric fluid.

Disadvantages of Spark Erosion
1. Eroding tends to affect the corrosion resistance of titanium.
2. Skilled personnel and specialized lab equipment is mandatory.
3. The high cost of the technique limits its usage.

Summary
An overview of the mechanism of action and applications of the spark erosion process in dentistry is presented. Such advances in dental technology help attain a passive fit of implant prostheses and fixed partial restorations, which is imperative in avoiding failures. The cutting-edge accuracy thus achieved, helps perfect critical adjustments in individual components thereby increasing the quality of treatment and hence, patient contentment and clinical success.

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