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ORIGINAL RESEARCH

Evaluation of Electric Discharge Machining to achieve Passive Fit of Implant Superstructure: An *in vitro* Study

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ABSTRACT

Objective: To evaluate marginal discrepancies between cast implant superstructure and EDM processed implant structure.

Materials and methods: For the purpose of this study, an experimental model was prepared on which nine cast implant superstructure in nickel-chromium were fabricated which was then subjected to EDM processing. One-screw test was used to verify fit of superstructure both pre- and post-EDM processing. Photo/Image analyzer was used to evaluate the marginal discrepancy. To reduce the error of measurement, nine readings were taken of each implant abutment junction, i.e. overall 324 readings pre- and post-EDM processing was made.

Results: All implant superstructure fabricated by investment casting procedure in nickel-chromium alloy showed negative one-screw test, i.e. they were fitting actively on abutment head and were sitting passively after EDM processing. Mean marginal opening of cast implant superstructure before EDM processing was 95.93 microns and 22.76 microns after EDM processing.

Conclusion: Nickel-chromium alloy can be used for fabrication of implant superstructure with EDM as programmed refining procedure to achieve passive fit.

Keywords: Electric discharge machining, Implant, Marginal fit, Superstructure.

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INTRODUCTION

The method currently used in India to produce a implant metallic superstructure with passive fit is the investment casting technique. However, Goll GE[1] has shown that 25% of metallic superstructures for full-arch restorations do not fit accurately despite the most meticulous attention to detail.

A multitude of clinical and laboratory inaccuracies exist that contribute to errors in the fit of restoration. Various methods are used to detect discrepancies and correct them. Sectioning of the framework and soldering is routinely followed. These procedures are tedious, expensive and time consuming and require additional patient appointments. The strength of the superstructure is also decreased. Another method to achieve fit by grinding the inner surface with burs is arbitrary and does not produce passive fit. To overcome these problems electric discharge machining has been suggested in literature.[2-6] It is a metal removal process where two electrodes are used to produce a spark. The anode (positive electrode) is the work piece itself and the cathode (negative electrode) is the tool, shaped with the inverse of the detail required. The discharges are produced by a DC power supply, which is connected to the two electrodes and travel through the dielectric fluid, ionizing it. Thermal energy is produced in the form of localized heat and the temperature reaches approximately 12000°C, which is sufficient to melt and vaporize the material.

This study was designed to evaluate marginal discrepancies between cast implant, superstructure and EDM-processed implant structure.

MATERIALS AND METHODS

1. Fabrication of experimental model.
2. Casting of implant superstructure.
3. One-screw test of implant superstructure.
4. Photo/Image analysis of implant superstructure.
5. EDM processing of casted implant superstructure.

Experimental Model

An experimental model was designed for the study. It composed of a horseshoe shape carbon steel base (Fig. 1), which was wire cut machine from single block. The shape of the model was elliptical with 110 mm major axis and 70 mm minor axis, the cross-sectional width was 10 mm, height 15 mm. To house the abutment heads in cuspid and bicuspid region four holes were drilled. The distance between the center of holes was 15, 24 and 15 mm from left to right and the diameter of holes was 5 mm. Four nickel coated abutment heads and forty copper electrode heads were turned on a computerized numerically controlled turning center machine.

The abutment head has a housing assembly 6 mm in length and 5 mm in diameter that has been tapped with M3 tap, for provision of coupling assembly with a 12 mm long and 3 mm in diameter screw. The top of abutment head (Fig. 2) has a M2.5 tap for a 2.5 mm diameter and 3 mm long screw, which will secure the implant superstructure to abutment head. The difference in dimension between copper electrode (Fig. 3) and nickel coated abutment head was decided taking into account the spark gap required to

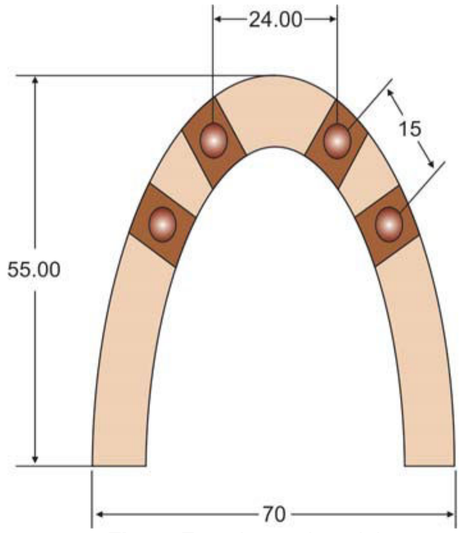


Fig. 1: Experimental model

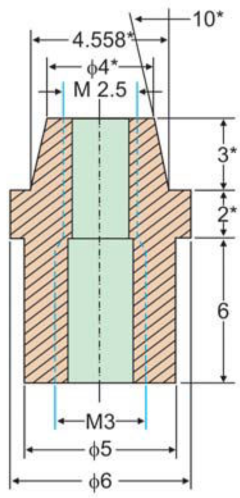


Fig. 2: Abutment head

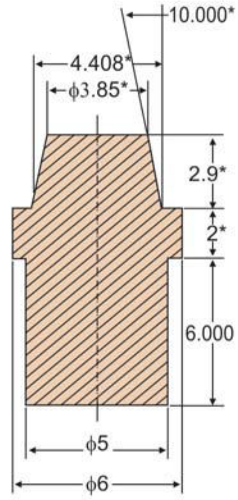


Fig. 3: Copper abutment head replica as electrode

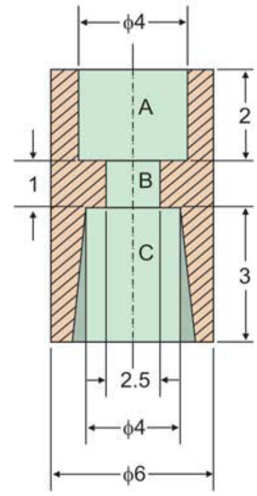


Fig. 4: Plastic casting sleeve

accurately machine the work piece (cast implant framework).

Fabrication of Cast Implant Superstructure by Lost Wax Technique Wax-Up

Four nickel coated abutments were screwed into the horseshoe shaped base assembly with the 3 mm in diameter and 12 mm long screws and checked for tight coupling between these two parts. For accuracy, 40 polypropylene casting sleeves (Fig. 4) were prepared with injection molding techniques. These sleeves had an outer dimension of 6 mm.These casting plastic sleeves were screwed with 2.5 mm diameter and 3 mm long screws on the nickel coated abutment head. Wax sprue, 3 mm in diameter was used to connect these sleeves and a cantilever of 5 mm was waxed up on distal sleeves. The wax sprue had clearance of 4 mm from the base.

Spruing and Investing

A horizontal wax sprue of 3 mm diameter was connected between distal abutments to prevent contracture of framework in horizontal plane. Four wax sprues of 3 mm diameter were attached to the top of the connecting and horizontal bar. The wax-up was kept for 2 hours before investing. The whole assembly was carefully unscrewed and the fit was verified. The sprue assembly was luted to the rubber custom sprue base. The metal casting ring was coated with two layers of ceramic liner. The liner was moistened with water and positioned 5 mm from the upper margin of the ring. A spray was used for reducing surface tension and dried lightly. Bellavest 320 gm was vacuum mixed with 80 ml liquid (70 ml special liquid and 10 ml distilled water) then poured into the ring with the help of a vibrator. The investment was allowed to set for 1 hour.

Casting

Ring was placed in burnt out furnace (Superfici-Calde, Italy) for 1/2 hour at 250°C and then transferred to a heating furnace (Aseg Galloni-Italy). Total heating time was 2.5 hours. Total 16 gm of base metal (nickel-chromium) alloy bellabond N was used (2 pellets), to obtain a buttonless casting technical specification of bellabond N and physical properties according to DIN EN 150 9693. The metal was casted in a centrifugal induction-casting machine (Aseg Galloni, Italy) at 1350°C. The casting ring was bench cooled at room temperature and then divested and sand blasted with 25 micron aluminum oxide. The sprue was separated with a slim disk.

Photo/Image Analysis

The castings were manually inserted in the master model and enlarged at various points with 30x stereomicroscope with photo/image analysis system. The resulting images were stored in a computer as tagged image file format (TIFF).

The methods of selecting enlargement points were as follows:

Three sites were selected two from the buccal and one from lingual. In this way three images per abutment and 12 per castings was recorded. Since, there were nine castings, 108 images at 30× magnification were obtained. Each image was subjected to three measurements to reduce operator variability. Thus, nine measurements were obtained per abutment head. As there were four abutment heads, 36 measurements were obtained per castings. Nine castings required 324 measurements. The data was transferred to a calculation program (Microsoft Excel). Mean of nine measurements at each abutment head sites was calculated and considered as representative for that side.

One-Screw Test[7,8]

A screwdriver was used to tighten the original abutments to the bar. Only one screw was used to bolt the bar to the abutment head. The fit of the superstructure was verified at each of the four-implant abutment heads and the superstructure at the margin before EDM processing.

After the measurements the castings were subjected to EDM processing.

EDM Machining of the Prosthesis (Fig. 5)

The implant abutment replica was substituted with copper electrode, which was screwed into a horseshoe shaped base. Now, the cast superstructure and the base were mounted on electrical discharge machine unit creating two electrodes.

WORK PIECE—CAST IMPLANT SUPERSTRUCTURE

Tool Electrode—Copper Abutment Head Analog on the Horseshoe Shape Base

The spark erosion process for EDM 2000 has reciprocal polarity. As a result during machining, the implant analogs will alter, so they must be exchanged for copper electrode before erosion process begins. New electrodes are used for each sequence. The following procedures ensured the fit of the superstructure:

1. The superstructure was eroded with the copper electrodes for 10 minutes. The electrodes altered during this process.
2. The altered electrodes were replaced with new electrodes and the bar was machined for another 1 minute to finish the superstructure.

It was essential to program the generator so that most of the machining was directed to the primary bar and not to the copper electrodes on the implant cast.

Castings after EDM processing were again subjected to photo/image analysis and one-screw test.

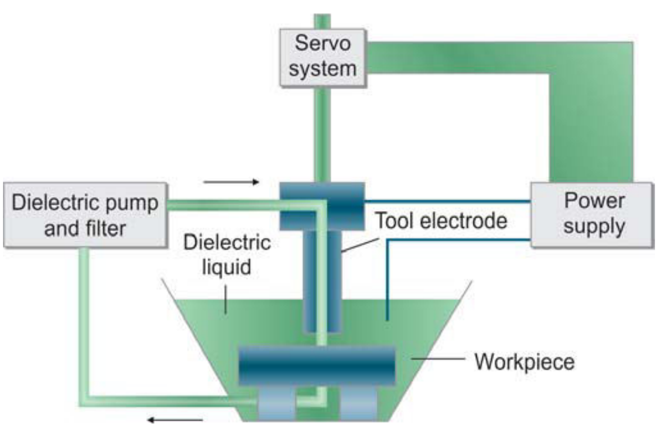


Fig. 5: EDM machining of the prosthesis

Summary of the method use to fabricate passive cast implant superstructure with electric discharged machining process.

Abutment head: CNC turned copper electrodes with spark gap calculations wax-up of superstructure—investment of wax pattern—casting of framework—evaluation of fit of framework—EDM prosthesis—passive fit of superstructure.

RESULTS

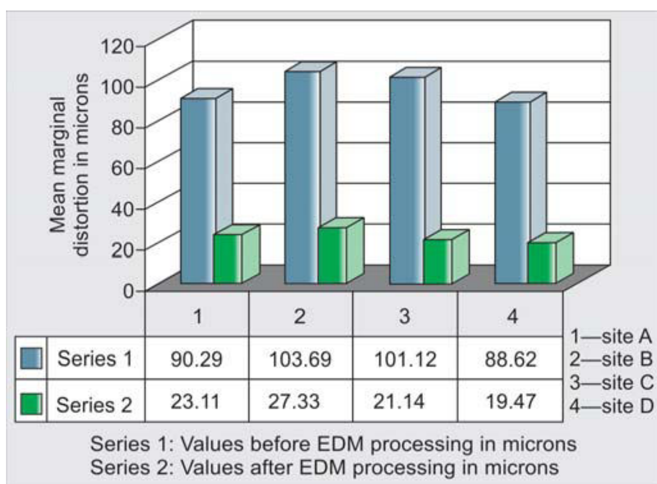
Statistical analysis using students t-test was carried out. There is significant statistical difference between marginal opening before and after EDM processing (Graph 1).

1. All implant superstructure fabricated by investment casting procedure in nickel-chromium alloy showed negative one-screw test, i.e. they were fitting actively on abutment head.
2. Mean marginal opening of cast implant superstructure before EDM processing was 95.93 microns.
3. Mean marginal opening of cast implant superstructure after EDM processing was 22.76 microns.
4. On EDM processing all nine castings showed a positive one-screw test, i.e. they were fitting passively on the model.

DISCUSSION

There are two implant framework fabrication techniques that are currently used in a majority of clinical situations. One involves copy-milling sections in titanium and laser welding the sections together. The other is the conventional lost wax technique, which is used to cast one-piece full arch implant frameworks, which is economical and widely used in Indian laboratories.

If clinical fit of a framework to implant abutments is not obtained then sectioning and soldering procedure is a



Graph 1: Mean marginal distortion of implant superstructures before and after EDM processing at sites A, B, C and D

common strategy to improve the fit of the framework to implant abutment. Stephen J Riedy,[8] ZoidusPC[9] studied the effect of soldering, electrowelding and cast to procedures on accuracy of fit of cast implant bars. Mean vertical opening at implant abutment interface was, 44 microns for cast-to-procedures, 86.5 microns for soldering and 240.70 microns for electrowelding. The three connecting procedures yield different results in regard to accuracy of fit of cast gold implant bars. The electrowelding procedure was technique sensitive, inaccurate and unpredictable. The soldering procedure was inaccurate for connecting implant bar and cast to procedure was consistent and predictable but not accurate enough to be used routinely. The problem with all the three connecting procedures was that the framework needs to be sectioned and welded or soldered together, wherein maintenance of work hardening properties of one-piece casting was difficult to achieve.

In India, none of the laboratories utilize machined gold cylinder. All the superstructures are casted as one piece in base metal alloys. As observed in the study, mean vertical opening for casted implant superstructure and abutment interface was 95.93 microns. Thus, it seems obvious that standard method for correcting the misfit ought to be available for use on routine bases. In this study, clinical and some laboratory variables were excluded to better evaluate the casting technique itself and the effect of programmed refining procedure by EDM on implant superstructure fabrication.

The test model had a dimension of 70 to 55 mm. The quantity of metal used to fabricate the superstructure was thus the greatest possible, amplifying technical problems. The metal used was nickel, chromium, which is used most commonly in India, as it is less expensive. The casting for the superstructure was horseshoe shaped, which is known to cause maximum distortion during fabrication. The fitting surface of the superstructure was sandblasted before checking fit. Image analyzer was used to evaluate the marginal discrepancy because it was not possible to put the experimental model in SEM chamber. Digital images were selected because it permitted verification of line measurements over light microscope. To reduce the error of measurement, nine readings were taken of each implant abutment junction, i.e. overall 324 readings pre- and post processing was made.

From the result of the study it would appear that assemblies that used cast implant superstructure show greater magnitude of vertical discrepancies at external abutment implant junction.

Most of the studies were carried out on titanium superstructures. This study aimed to study the effect of EDM refining process on nickel-chromium alloy as superstructure. On EDM processing mean marginal opening was 22.76 microns and statistical data showed uniform distribution. Statistical analysis using students t-test was carried out. There is significant statistical difference between marginal opening before and after EDM processing (Graph 1).

There was no machined component (gold cylinders) used, but machined programmed refining was carried out.

1. Metal experimental model was used to simulate clinical situation and for convenience, so that it could be used as a single unit, which could be clamped to one of the electrodes of EDM 2000 machines.
2. The abutment heads were manufactured indigenously, so that machining tolerance could be same for abutment and copper electrodes.
3. Abutment head had outer dimension of 6 mm while in clinical situation largest size is 5 mm. This was done as available CNC machine could not accurately turn small abutment heads with a given degree of precision.
4. A 0.1 mm discrepancy was kept overall between abutment heads and electrodes to take into account spark gap required to machine superstructures.
5. Only vertical marginal discrepancies were taken into consideration as die sinking EDM can correct casting errors in only one axis.

For correction of errors in two (vertical and horizontal) axes die sinking EDM should be combined with wire cut EDM. wire cut EDM would mill external surface of superstructure and die sinking EDM would mill the mating surface of implant superstructure.

Out of all the corrective refining procedures available for fabrication of passive implant superstructures, EDM offers the following advantages Rubeling G, S Kreylos H:[10]

1. It is not affected by metal hardness because it is a thermal process.
2. Adhesive characteristics of the work piece do not affect the process because it is a noncontact method of removing metal.
3. EDM provides a smooth bur-free surface.
4. Process can be used to machine thin objects without distortion because there are virtually no mechanical forces created.
5. EDM is accurate to within 20 to 30 microns, which is the most accurate among currently available refining processes.
6. Superstructure need not be sectioned to obtain passive fit.

These characteristics make the process desirable to the dental profession. The EDM facilities are routinely and economically available in the Indian industry. The manufacturers of implant components need to design copper electrodes with calculated spark gaps so that laboratory personnel can use this facility.

In future, the machining programming variables, like dielectric amp, voltage, need to be evaluated to measure its effect on machining accuracy of superstructure with EDM.

CONCLUSION

- None of the cast implant superstructure fitted passively on the experimental model before EDM processing.
- All EDM processed superstructure, showed positive one-screw test, i.e. they fitted passively on abutment head.
- The results show that nickle-chromium alloy can be used for fabrication of implant superstructure with EDM as programmed refining procedure to achieve passive fit.

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