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Is the Passive Fit of the Cast in One-Piece Screw-Retained Dental Implant Superstructures Feasible? Theoretical Considerations

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Abstract: The aim of this study was to theoretically evaluate whether the passivity of the fit of the cast in one-piece screw retained dental implant-supported prosthesis is feasible. A mathematical approach was used for the purposes of this study. It was proved that the distortion of the cast in one-piece screw retained dental implant prosthesis is inevitable. Any effort for the fabrication of a cast in one-piece implant screw retained superstructure with a passive fit is impracticable. This is due to the involvement of too many materials and technical factors. The summation of the small independent distortions that these factors cause cannot total to zero.

Key words: Screw-retained dental implant superstructures, passive fit of dental implant prostheses

INTRODUCTION

Dental implants constitute a predictable treatment modality for fully or partially edentulous patients seeking prosthetic rehabilitation. The retention of the dental prostheses to the abutments-which are connected to the osseointegrated implants-can be either achieved with screws or with cement. Screw-retained implant prostheses are used more often than the cement-retained ones because they offer the advantage of retrievability.

The connection of screw-retained superstructures to the implants has to be passive in order to avoid future complications, such as loosening or breakage of the fastening screws[1-3] or even worse, fracture of the implants[4,5]. By the term passive fit we mean the fit of the prosthesis to the osseointegrated implant fixtures that does not induce any strain into the bone-implant-prosthesis complex. Skalak[6] has presented a theory according to which non-passive frameworks can cause biological and prosthetic complications. However, recent research on laboratory animals[7,8] and limited clinical studies[9-12] indicate that, it is possible that non-passive fit does not necessarily cause biomechanical problems to implant restorations. These findings though are based on short-term studies and should not affect the efforts of the clinicians for the quest of the passive fit of the implant prostheses.

The optimal procedure would be one that would permit the fabrication of a screw-retained superstructure cast in one-piece, fitting perfectly in every implant fixture. However, the fabrication of implant retained prostheses requires many clinical and laboratory stages, which should be very accurate[13-16]. Each stage in the fabrication process can result in a minute error, which may finally contribute to a distortion of the superstructure to the implant fixtures. Nichols[17-19] has defined the distortion that is possible to take place during the metal framework fabrication as the relative movement of a single point, or a group of points, away from some originally specified reference position such that permanent deformation is apparent. The positional distortion that Nichols referred to, can occur 3 dimensionally in a rectilinear or in a curvilinear way. It should be mentioned that a single point by virtue is incapable of rotation[20]. This distortion of the superstructure can happen at any stage from the impression to the delivery of the prosthesis to the patient and it is expressed with the distortion equation. This equation represents the summation of all small

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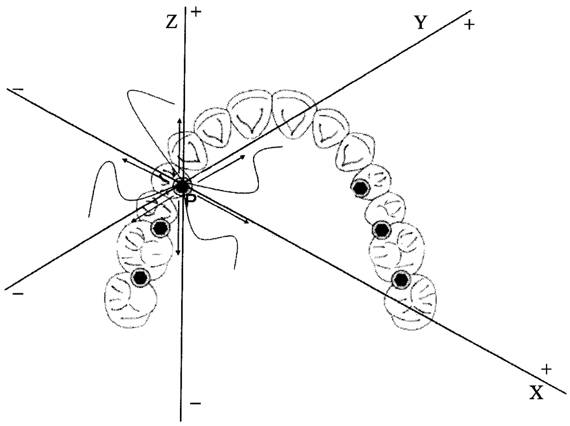

Fig. 1: A single point P can present a movement along a rectilinear (dx, dy, dz) and a curvilinear path ($d\theta_x$, $d\theta_y$, $d\theta_z$), or a combination of these. This movement is caused by the distortion of the prosthesis during the fabrication procedure

independent distortions that happen during the different stages of the fabrication procedure. When the sum of these distortions is zero, then a passive fit is achieved. The question that arises is, whether the passivity of the fit of the cast in one-piece screw-retained superstructure is feasible.

The purpose of this study was to theoretically evaluate if the passivity of fit of the cast in one-piece screw-retained superstructures is obtainable.

Theoretical considerations regarding the problem: A single point P, or a group of points $P_1,P_2,\ldots,P_n$, of the cast in one-piece screw-retained superstructure may theoretically move along a rectilinear path in three directions into a Cartesian coordinate system, namely dx, dy and dz. It is possible that the same points $(P_1,P_2,\ldots,P_n)$* can also perform a curvilinear movement, namely $d\theta_x$, $d\theta_y$, $d\theta_z$or even a combination of these. (Fig. 1)

In order to have no movement-rectilinear or curvilinear-of the single point (P), it should be:

$$dx+dy+dz+d\theta_x+d\theta_y+d\theta_z = 0$$

From the time of the impression till the delivery of the screw-retained prostheses, there are several factors involved, which can cause minute distortions. These are as follows:

u_1 = impression procedure
u_2 = definitive cast fabrication
u_3 = wax pattern fabrication
u_4 = investing procedure
u_5 = casting procedure
u_6 = porcelain firing
u_7 = tolerance of the implant components

The distortion of each factor can be represented by a vector, since it has both a magnitude and a direction. Let this distortion of each factor be du.

In order to have no movement-rectilinear or curvilinear-of the single point P, the independent distortions of each factor should sum to zero:

$$du_1+du_2+\ldots+du_7 = 0$$

So,

If $du_1+du_2+\ldots+du_7 = 0$ then, $dx+dy+dz+d\theta_x+d\theta_y+d\theta_z = 0$
If $du_1+du_2+\ldots+du_7$? 0 then, $dx+dy+dz+d\theta_x+d\theta_y+d\theta_z$? 0

In order to have $du_1+du_2+\ldots+du_7 = 0$, there are two hypotheses:

1. Each one of the $du_1, du_2,\ldots,du_7$ is equal to zero.
2. Some of the $du_1, du_2,\ldots,du_7$ have positive values (positive vectors) while some others have negative values (negative vectors), summing to zero.

According to previous studies, the following facts should be considered:

- No impression material has 100% dimensional stability and elastic recovery[21,22]. Thus $du_1 \neq 0$.
- All dental stones, used for the fabrication of master casts present some expansion, ranging from 0.1 % for type IV to 0.3% for type V[23]. Therefore $du_2 \neq 0$.
- Wax is the dental material with the highest coefficient of thermal expansion. Its dimensional stability is closely related to environment temperature changes. Wax can shrink as much as 0.4% on cooling from liquid to solid. Additionally wax patterns can release stresses that were incorporated into them during handling, due to the lack of uniform heating[24]. So, $du_3 \neq 0$.
- Expansion of the investment: High heat phosphate-bonded investments have a setting expansion that ranges between 0.23% and 0.50%. They also present a hygroscopic expansion of 0.35-1.20% and a thermal expansion of 1.33-1.58% (700°C)[25]. Thus $du_4 \neq 0$.
- Shrinkage of the metal: The thermal contraction of the dental alloys ranges between 1.42% for a type III and 1.56% for a type I[26]. Hence, $du_5 \neq 0$.

- During the firing of the porcelain: It has been demonstrated by Bridger and Nichols that distortion occurs in curved, long span frameworks during the porcelain firing cycle. The pattern of this distortion is a closing of the posterior or lingual dimensions and a labial movement in the anterior dimension of the fixed partial denture. This deformation results from changes in the metal, as well as from the contraction of fired porcelain[27]. So, $du_6 \neq 0$.
- Tolerance between the implant components: It has been documented that tolerance in critical areas of implant components ranges from±3.0 to±101.6 µm, depending on different manufacturers[28]. Thus, $du_7 \neq 0$.
- Taking all of the above findings into consideration, the first hypothesis that $du_1 = du_2 = \ldots = du_7 = 0$, should be rejected.

So, in order not to have any positional (recti- or curvi-linear) distortion of the superstructure ($dx+dy+dz+d\theta_x+d\theta_y+d\theta_z = 0$), the second hypothesis should be accepted.

Consequently, if it is proven that the second hypothesis is incorrect, then

$$dx+dy+dz+d\theta_x+d\theta_y+d\theta_z \neq 0,$$

which means that there will be some movement of point P and therefore a distortion of the screw-retained superstructure will occur.

Each distortion du can be broken down into two parts[29]:

$$du = b \pm \Delta du,$$

where b is a known deviation (it can be perceived as a bias in a measuring instrument or as a predicted value of a known procedure) and Δdu is the imprecision (respectively imprecision of an instrument or deviation or unpredicted deviation of a known procedure).

Then,

$$\sum_{n=7} du_n = du_1 + du_2 + \ldots + du_7$$

becomes

$$\sum_{n=7} du_n = (b_1 \pm \Delta du_1) + (b_2 \pm \Delta du_2) + \ldots + (b_7 \pm du_7)$$

Since b's are known, they can be forced to sum zero (in the fabrication procedure b's are accounted for by preselecting material and/or manufacturing location points).

Then imprecision Δdu (which drives the uncertainty) can be used as absolute error[29],

$$E_t = |\Delta du|$$

Consequently the total error (E_t) is given by,

$$E_t \sum_{n=7} |\Delta du_n|$$

and

$E_t \neq 0$, since always imprecision $\Delta du_n \neq 0$

Thus, the second hypothesis should be rejected too.

Consequently,

$$dx + dy + dz + d\theta_x + d\theta_y + d\theta_z \neq 0,$$

which means that there will always be a distortion of the cast in one-piece screw retained superstructure. From an engineering point of view the total error (E_t) is the maximum error expected. So, the cast in one-piece screw retained superstructure's imprecision is bounded by E_t.

DISCUSSION

This study has demonstrated that a distortion of the cast in one-piece screw-retained superstructure is theoretically inevitable. From an engineering point of view it seems that, a distortion can probably occur even if only two implants are connected with such a type of prosthesis. The distortion is due to the involvement of too many variables that cannot be absolutely controlled. In the approach of the problem only the materials related factors have been included for simplification reasons. In the reality though there is an involvement of other factors too, such as environment conditions, ability of the operator, etc.

Many researchers have tried both *in vivo* and *in vitro* to fabricate screw-retained implant superstructures with a passive fit[30-40]. Until today the results of these studies indicate that this is not feasible. The approach of this paper presents a theoretical basis for the limitations of the procedure for the fabrication of the cast in one-piece screw-retained superstructure.

As mentioned before, the material factors involved in the construction of a prosthesis are: (1) impression material, (2) dental stone, (3) wax or acrylic resin, (4) investment, (5) alloy, (6) porcelain and (7) implant components.

Some of these materials present an expansion (e.g., dental stone and investment) while some others (e.g., acrylic resin and alloy) a contraction. The whole procedure and the materials have been designed in such a way that opponent factors could theoretically be neutralized, in order to have an accurate fit of the prostheses. In traditional fixed prosthodontics this methodology works because:

- In the crowns, there is an internal space of 20 to 40 μm, provided for the luting agent. This internal space implies that, a complete crown has an internal diameter between 40 and 80 μm larger than the diameter of the prepared tooth[41]. This space probably provides a freedom to the prostheses,which allows it to have a potential passive fit on all abutments simultaneously. Thesame concept is applied to cemented implant prostheses. This is actually one of the main reasons that made these restorations popular.
- All teeth present a physiologic mobility, which varies[42]. Tooth mobility occurs in two stages: (a) the initial or intasocket stage, in which the tooth moves within the confines of the periodontal ligament[43]. This movement occurs with forces of about 100 pounds and it ranges between 50-100 μm[44] and (b) the secondary stage, which occurs gradually and entails elastic deformation of the alveolar bone in response to increased horizontal forces[44]. It usually occurs when a force of 500 pounds is applied and it is between 8-10 μm for the premolars, 40-80 μm for the molars, 50-90 μm for the canines and 100-200 μm for the incisors[45].

On the other hand, the same procedure does not obtain the desired results in implants, because:

- In screw-retained prostheses, the rigid joint that the fastening screws offer does not permit the required "freedom" for the desired passive fit. On the contrary, the screws can draw misfitting components together with a clamping force. This introduces strain in the implant-restoration system[46].
- In contrast to natural teeth, osseointegrated implants do not present any clinical mobility. The slightest increase in mobility indicates the development of a problem[47].

It is true that, each one of the above-mentioned factors that affect the fabrication procedure presents a minute distortion, which by itself would probably be insignificant. However, the summation of all independent small errors may result in a distortion, which can cause significant internal stress to the prosthesis-implant-bone complex. These stresses may be tolerated by the system, but there is also an increased possibility to lead in biological and/or prosthetic complications.

The clinician should be very critical about the passivity of fit of the screw-retained implant supported prostheses, since, as it was shown by this study and other clinical and laboratory research projects, this is not obtainable, at least with the cast in one-piece procedure. Soldering procedures should be performed routinely. Other methodologies which include precise machining procedures may be proven helpful too.

CONCLUSION

The theoretical considerations of this study indicate that any effort for the fabrication of a passive cast in one-piece implant screw-retained superstructure seems to be unfeasible. This is due to the involvement of too many material and technical factors, which individually, can cause a very small distortion. The summation of all these distortions cannot sum to zero. Other methods to obtain a passive fit of this type of prostheses should be developed.

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