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Research Article

Effects of cyclic loading and thermo cycling on screw loosening in dental implant

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ABSTRACT

The long-term success of dental implants has been well established in the literature, and numerous investigators have documented the biological factors, surgical procedures, and restorative principles that influence the outcome of implant-supported restorations. This review article describes the Effects of cyclic loading and thermo cycling on screw loosing, including results of current in vitro studies and the clinical performance of these restorations. An electronic search has been conducted, during 2016, via PubMed and Medline database English literature. Peer-reviewed articles were targeted following key-words have been used: Fracture resistance", "Cyclic loading", "Thermocycling", "Marginal gap", "Micro leakage", "Abutment implant connection and Screw loosing.

Keywords: Cyclic loading, Thermocycling, Marginal gap, Screw loosing

INTRODUCTION

Implant dentistry has become one of the most successful rehabilitation techniques among medical and dental specialties also called biomedical technique. Over the last 30 years, clinical evidence has shown excellent long-term results for osseointegrated implants with success rate above 90% (Hecker et al. 2003). However, this predictable treatment requires a dynamic equilibrium between mechanical and biological factors. Mechanical factors, such as the implant-abutment precise fit and the abutment screw preload, are involved in the success of implant rehabilitation. The preload loss during the occlusal load with the prosthesis in function favors the misfit of the implant-abutment connection and this can result in stress increase in the implant and connection components, and consequently in the surrounding bone (Broggini et al. 2006). Moreover, the stress at connection components could cause screw fracture and loss, abutment and prosthesis damage, requiring the repair or replacement of the prosthesis and its components (Weng et al. 2008).

This review article describes the Effects of cyclic loading and thermo cycling on screw loosing, including results of current in vitro studies and the clinical performance of these restorations. An electronic search has been conducted, during

2016, via PubMed and Medline database English literature. Peer-reviewed articles were targeted following key-words have been used: Fracture resistance", "Cyclic loading", "Thermocycling", "Marginal gap", "Micro leakage", "Abutment implant connection and Screw loosing. Available full-text articles were read. Related articles were also scrutinized. Hand search was also driven.

MATERIAL AND METHODS

The keywords used for the literature search for this review were Cyclic loading × Thermocycling × Marginal gap × Screw loosing. The search was carried out using Biological Abstracts, Chemical Abstracts, and the data bank of the PubMed and Medline database updated to 2016. The references found in the search were then studied in detail.

CYCLIC LOADING

Compressive cyclic loading is one such condition that may be employed to simulate occlusal stresses encountered in the oral environment and may affect the retentive properties of dental cements. Kaidonis et al (1998) in their investigation into wear of human enamel, and in using the same tooth wear machine as the current study, proposed weighted cyclic compressive loading of between 2kg and 10kg represented average human masticatory force. No significant difference in wear rates existed between running specimens at 80 or 160 cycles per minute, where one functional wear cycle constituted a uni-directional movement where a moving upper specimen was rubbed against a fixed lower specimen in one direction for a specified duration with a specified weight (Kaidonis et al, 1998). Also, Kaar et al (2006) investigated three luting agents used to cement gold cylinders to CeraOne abutments before and after 300,000 compressive cyclic loadings with a 100N (10.2kg) load. Specimens in this study were placed in a humidifier at37ºC and 100% humidity for 84 hours, but not thermocycled. Kaar et al (2006) found TempBond exhibited no significant loss of retention with the mechanical stressing employed in this study; however its retention value was the least of the three tested cements both before and after compressive cyclic loading.

Ongthiemsak et al (2005) investigated the effect of compressive cyclic loading on the retention of TempBond used to cement gold castings to Zimmer abutments. These authors subjected cemented specimens to compressive cyclic loading that simulated an estimated six months, one year and five years of human mastication, and found compressive cyclic loading reduced the retentive forces opposing crown removal in each group. Ongthiemsak et al (2005) found that although compressive cyclic loading reduced the tensile force necessary to remove a coping from an abutment, the increased number of cycles beyond six months had little relationship to further decreased retentive forces of the temporary cement.

The equivalent of six months loading caused 16.75% reduction in retention compared to no loading, one year caused 18.73% reduction and five years caused 19.68% reduction. Further cyclic loading beyond six months did not cause significant further loss of retention. This finding may raise the question of how rapidly retention is lost during the first six months of simulated function. These researchers stated "masticatory forces cause fatigue to cement-retained crowns and abutments and may adversely effect retention". However, their study was limited to the use of TempBond temporary cement.

THERMOCYCLING

Thermocycling is a widely acceptable method used in in vitro microleakage studies although some researchers consider it a questionable method (Hakimeh et al. 2001). The question is about the validity and clinical significance of the thermocycling method, since the temperatures used to stress restorations may not be the real temperatures of cold and hot food/beverage tolerated by patients (Gale and Darvell, 1999). In the thermocycling method, specimens are submitted to thermal cycles that simulate the intraoral temperature. However, the literature shows that there is a wide range in temperature extremes, transfer times between baths and dwell times. Thus, there is no standard for thermocycling methodology in microleakage studies, and this permits contradictory discussions and results in various laboratory studies (Schuckar et al. 1997).

Measurements of thermal changes beneath restorations in vivo have been accomplished with various materials ranging from amalgam to resin restoratives. Harper et al. (1980) suggested that there are very slow rates of thermal diffusion through composites, silicates and unfilled resin materials. Additionally, it was questioned as to how long patients can tolerate exposure to extreme temperature ranges which thermocycling would impose. In other studies involving thermocycling, Kerby et al (1992) reported slightly smaller retention values for cemented posts in Steri-Oss implants when thermocyled 1000 times. Uchiyama (1986) demonstrated a 1-5% reduction in retention of shear bond to failure values when discs were cemented to teeth with resin cements and thermocycled 300 times. When the same samples were exposed to compressive cyclic loading alone, a 2% to 10% reduction in retention values was observed. Diaz-Arnold (1989) reported no significant difference in retentive strengths of nickel-chromium-beryllium alloy discs cemented with three resin cements and thermocycled 300 times.

Matsumura et al (1990) suggested thermocycling was a technique that accelerated water aging deterioration. In their study of adhesive bonding of titanium with a titanate coupler, no significant difference in retention was demonstrated between 20,000 and 50,000 thermocycled specimens. This, and previous findings from studies involving thermocycling, may possibly be explained by looking at the thermocycling process and / or the material being tested. Thermocycling may simulate some oral thermal stresses but in a different manner to those actually encountered in vivo.

The materials tested may be affected by a small quantity of thermocycling up to a point, after which further thermocycling had a minimal measurable effect. The importance of considering the coefficients of thermal expansion of the materials being tested has been previously mentioned. It has not yet been possible to equate quantities of thermocycles with equivalent in vivo time. Nevertheless, it was apparent thermocycling had at least some effect on in vitro samples, albeit sometimes statistically insignificantly, and should be used during in vitro studies to simulate the oral environment (Ongthiemsak et al. 2005).

MICRO LEAKAGE

Two-part dental implant systems that use screw retained abutments are still commonly used by clinicians as a result of their well-documented protocol in the literature, high success rates, and broad spectrum of indications. However, these systems present a major drawback of gaps and cavities in the assemblies after the implant and abutment are connected (García-Bellosta et al. 2010).

These hollow spaces may act as reservoirs for commensal and/or pathogenic bacteria, especially anaerobic or microaerophilic species, representing a potential source of tissue inflammation that may lead to bone resorption. Many in vitro studies have demonstrated bacterial leakage along the implant-abutment interface of several implant connections under unloaded conditions (Jung et al. 2008).

These gaps can be further enlarged under loading when the implant assembly components are subjected to eccentric forces. Screw loosening and decrease in screw joint preload below a critical level may contribute to joint instability, causing clinical failure. Also, micro movements of the implant components during function may allow the initiation of a pumping effect, causing bacteria to move through the implant abutment interface (Tabanella et al. 2009). However, because of difficulties with handling and culturing, most studies published on this issue have evaluated bacterial leakage only under unloaded conditions.

Also, generally, microorganisms unrelated to the etiology of periodontal or peri-implant diseases have been investigated. The oral microbiota comprises a complex of several species with different sizes and forms, which may or may not be associated with infectious diseases. Also, the nutrients and immunologic factors present in the human saliva can influence bacterial penetration along the interface (Botero et al. 2005).

LEAKAGE OF IMPLANTS UNDER THERMO-MECHANICAL LOADING

Some studies showed leakage to be a dynamic process, which could not be detected under static conditions only (Steinebrunner et al. 2005). Implants do experience different physical conditions under functional loading like a pumping effect due to the vertical forces in the occlusal direction and luxation forces in the axial occlusal direction. In general, however, implant leakage studies under thermo-mechanical loading, were limited to the implants seal performance under loading without considering the preloading status of mounted implants again. The need to disassemble the abutments to cultivate samples of the inner implant chamber illustrates limitation of implant testing at different stages (Koutouzis et al. 2011). The lack of information about the leakage development in the course of implanting process, may potentially lead to false conclusions about the reason behind the leakage.

None of the available studies can explain underlying causes of leakage, whether it is due to mechanical failure due to thermo-mechanical loading or simply because of misfits from the beginning due to manufacturing problems (Zielak et al. 2011).

ABUTMENT IMPLANT CONNECTION

The first implant-abutment connection design used by Branemark system was external hex which was developed for rehabilitation of completely edentulous ridge. Under such circumstances, implants were connected together with a metal bar as the artificial retainer of the complete denture (Binon, 2000). The influence of the type of connection on the long-term stability of the abutment-implant complex has been analyzed for titanium abutments in several studies. With this type of abutment, mechanical problems such as loosening or fracture of the abutment screw can occur with external connections (Jemt et al. 1990). In one clinical study of an external-connection implant system, loosening of the abutment screw was the most frequent technical complication observed after 3 years of service (Jemt et al. 1993).

In contrast, the internal conical connection was demonstrated to exhibit significantly higher strength in vitro than the external hexagonal connection owing to its higher resistance to bending. The occurrence of abutment screw fracture was lower with an internal connection (Khraisat et al. 2002). In one clinical study analyzing an internal-connection implant system, the cumulative survival rate for the abutment screws and the restorations supported by titanium abutments was 100% after 18 months, and no screw loosening or fracture occurred (Drago and O'Connor, 2006).

SCREW LOOSENING

Screw loosening has been reported to occur most often with single-tooth implant restorations but has also been reported in multiple-unit situations. Poorly fitting implant frameworks can potentially cause uneven thread contact, tension, and bending stresses of the connecting screw, therefore resulting in screw loosening and fractures, and marginal peri-implant bone loss (Alkan et al. 2004). In this regard, Piermatti et al. (2006) in vitro study about screw loosening in internal and external connections resulted in a different opinion. According to this study, screw loosening is mostly associated with the screw design and quality of screw material rather than the connection type (Albrektsson et al. 2013). There are several mechanisms that can cause screw loosening and loss of preload. One is the embedment relaxation of mating thread surfaces. New screws and bolts all possess some rough-textured thread surfaces as a result of the machining process. When the torque is applied, energy is dissipated in smoothing mating surfaces, reducing the elongation of the screw (Teixeira et al. 2011). An effective method to reduce screw loosening is to increase the screw preload and clamping force across the joint to ensure that the screw preload and clamping force are greater than the occlusal forces acting on the implant system. The maximum preload has been calculated to be a maximum of 75% of the strength of the screw. Screw strength is significantly related to the modulus of elasticity of the material from which the screw is manufactured. The values of 32-35 Ncm were established based upon gold screws made from materials with low moduli and yield strengths (Teixeira et al. 2011).

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