Evaluation of stress induced on different implant abutment connections used in implant supported mandibular overdenture

(3D finite element stress analysis)

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Introduction

Edentulism was found to be a global issue, with estimates for an increasing demand for complete denture prostheses in the future [(1)], it is defined as the loss of all permanent teeth [(2)] and is the terminal outcome of a multifactorial process involving biological factors and patient-related factors. It continues to represent a tremendous global health care burden, and will for the near future [(1)].

Endosteal implants are widely used because of the advantages offered by their mechanical properties and excellent anchorage in the jawbone, known as "osseointegration". This ankylotic anchorage of the titanium implant in bone is considered an essential criterion for a successful dental implant.

Manufacturers have developed various implant–abutment connection designs. These interface designs can be roughly divided into two groups. The first group may be described as butt joints or slip fit joints, with a passive connection and a slight space between implant and abutment. The second group comprises conical interface designs with friction fit joints.

Both types can be sub-classified into internal and external connection types. With the internal connection type, connective parts of the abutment are placed into the implant body. In contrast, an external connection type is observed when connective parts of the abutment enclose an extension of the implant body.

Biomechanics is the application of engineering mechanics (statics, dynamics, strength of materials, and stress analysis) to the solution of biological problems. Biomechanics pertains to dentistry because the teeth and jaw perform biomechanical activities during mastication. The implant

will transmit loading to the interfacial tissues around the implant, which then must tolerate them without adverse tissue response. [3]

Among the methods for the evaluation of implant biomechanics, three-dimensional (3D) finite-element analysis has been widely used for the quantitative evaluation of such stresses and strains in the bone due to technical limitations of stress assessment in bone in vivo. [4]

Finite Element Analysis (FEA) is a numerical stress analysis technique that is widely used to assess engineering and biomechanical problems before they occur, it is a powerful and effective tool for predicting the mechanical behavior of dental restorations, and implant supported prosthesis. [5]

FEA is a technique for obtaining a solution to a complex mechanical problem by dividing the problem domain into a collection of much smaller and simpler domains (elements) in which the field variables can be interpolated with the use of shape functions. An overall approximated solution to the original problem is determined based on variation principles.[6]

Because the components in a dental implant- bone system are extremely complex geometrically, FEA has been viewed as the most suitable tool to evaluate stresses induced on supporting structures influenced by different implant abutment connections. [6]

Review of literature

Edentulism is described as the loss of all permanent teeth[2] and is the terminal outcome of a multifactorial process involving biologic processes ; caries, periodontal disease, pulpal pathology, trauma, oral cancer, as well as non biologic factors related to dental procedures; access to care, patient preferences, treatment options, etc.[1]

Chronic oral disease represents an enormous global health care burden that is often neglected in developed and developing countries; because of its economic impact, and association with other life-threatening entities such as coronary artery disease, stroke, and cancer, the treatment of chronic oral diseases, including the completely edentulous condition, should not go unnoticed. [1]

The distribution and prevalence of complete edentulism between developed and less-developed countries may be associated with a complex inter relationship between cultural, individual, access to care, and socioeconomic factors.[1]

Complete edentulism is an international problem, particularly in the 65 years and older age groups,[7] World Health Organization databanks indicate that caries is still prevalent in the majority of countries internationally, with some reporting 100% incidence in their populations and the incidence of complete edentulism has been estimated between 7% and 69% internationally.[8]

Classification system for complete edentulism [9]

Class I

This classification level characterizes the stage of edentulism that is most apt to be successfully treated with complete dentures using conventional prosthodontic techniques. [10]

All of the following diagnostic criteria are favorable: residual bone height of 21 mm or greater measured at the least vertical height of the mandible on a panoramic radiograph, residual ridge morphology resists horizontal and vertical movement of the denture base; Type A maxilla, and class I maxilla-mandibular relationship.

Class II

This classification level distinguishes itself by the continued physical degradation of the denture supporting anatomy and is characterized by the early onset of systemic disease interactions, patient management, and/or lifestyle considerations.

The patients related to this classification have residual bone height of 16 to 20 mm measured at the least vertical height of the mandible on a panoramic radiograph, residual ridge morphology that resists horizontal and vertical movement of the denture base; Type A or B maxilla and class I maxilla-mandibular relationship.[10]

Class III

This classification level is characterized by the need for surgical revision of supporting structures to allow for adequate prosthodontic function. Additional factors now play a significant role in treatment outcomes such as, residual alveolar bone height of 11 to 15 mm measured at the least vertical height of the mandible on a panoramic radiograph, residual ridge

morphology has minimum influence to resist horizontal or vertical movement of the denture base; Type C maxilla and Class I, II, or III maxillomandibular relationship.

Class IV

This classification level depicts the most debilitated edentulous condition. Surgical reconstruction is almost always indicated but cannot always be accomplished because of the patient's health, preferences, dental history, and financial considerations. When surgical revision is not an option, prosthodontic techniques of a specialized nature must be used to achieve an adequate treatment outcome.

Residual ridge resorption

It is well known that removal of teeth leads to alveolar bone resorption. This response varies in extent among individuals, but appears to be a general occurrence that is inevitable for the majority of individuals experiencing complete tooth loss. Continued reduction in the alveolar bone volume leads to unstable clinical conditions that require awareness of the process and accommodation to it. [11]

Mandibular teeth extraction will result in a continual reduction in the alveolar bone volume which is more dramatic in the mandible than the maxilla. The continued resorption of the mandibular alveolar bone is associated with greater difficulty with mandibular denture construction, use, and satisfaction. The absence of teeth is also associated with reduced social and physiologic function.[12,13]

Oral implant placement may prevent the continued resorption of bone and has been associated with increased mandibular bone height distal to the implant location.[14]

Wright et al.[15] described an increase in the posterior mandibular bone height in response to functioning with implant-supported fixed dentures, but not overdentures. Subsequent contradictory findings indicated that implant-supported overdenture use was associated with mandibular bone resorption.[16]

Although positive bone responses are widely recognized following implant placement in the para symphyseal mandible, the extent of this benefit remains controversial and merits additional investigation. Posterior mandibular alveolar ridge resorption should be anticipated.[11]

The management of the edentulous patient involves continuous monitoring of residual alveolar ridge resorption and related issues of denture function. Clinical management of residual alveolar bone mass must be addressed. Beyond the promise of endosseous implants, the prevention or management of residual alveolar ridge resorption should be the second part of a contemporary strategy in the treatment of edentulism. [11]

Implant retained overdenture

Although the prevalence of edentulism is falling in all age groups, the number of older people is still increasing. As edentulism can be regarded as a handicap and is reported to affect oral and general health as well as overall quality of life, treatment of edentulism will continue to be a challenge for clinicians. [17–20]

For more than 100 years, conventional dentures were the only available treatment for edentulism. This classical treatment relies on the retention and support provided by remaining bone ridge, but many denture-wearing patients have a poor diet and cannot speak clearly due to lack of denture retention and stability. [21,22]