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Review Article

DENTAL IMPLANT DESIGN-A REVIEW OF LITERATURE

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ABSTRACT

This article gives an idea of the endosseous implant design, shape and its properties, primary stability and osseointegration and long term function.

INTRODUCTION

Per-Ingvar Branemark was the first to introduce endosseous dental implant, since then it continued to evolve. At the same time evolution in the thinking of the clinicians also occurred, before they use to simply think of restoring the edentulous place but now they think of aesthetic, osseointegration and long term function. The foundation of aesthetics starts from the design of the implant. The design of the implant will be so correct that it can sustain clinical situations.

Implant properties

Implants should not fracture, yield, fatigue, wear or otherwise fail during in vivo use. Failure prevention necessitates testing and stress analyses of the implants and tissues. Assuming there is accurate background data on typical implant loading the problem is to select adequate intrinsic and structural mechanical properties of implants. Intrinsic properties pertain to the material and not its shape. They include a material's elastic moduli, yield point, ultimate tensile strength, compressive strength, fatigue strength, and hardness. For corrosion behavior, intrinsic properties could also be defined. Values can be found in textbooks and literature, or they may be directly measured via standard test methods[1, 2, 3, 4]. Caution is advised in using handbook values, because manufacturing processes can cause significant property differences between raw material and the finished product.

Structural mechanical properties embody both the intrinsic material property and the geometrical shape of the device being considered. For example, the deformability of a beam in bending depends on the product EI (flexural rigidity), where E is Young's modulus of elasticity and I is the second moment of area of the beam's cross-section. The deflections of a cantilevered dental bridge could be inappropriate even when the bridge is made of a strong, high-modulus (E) dental alloy because its deflection under load will depend on both modulus and dimensions. There are handbooks and articles on proper structural design that can be applied to implant design[5, 6, 7].

Design means to create according to a plan[8,9]. The word design indicates a process, not an end product such as the particular shape or material of a dental implant. Shape and material are only two of the many considerations in the multivariable design problem for dental implants. The design process is a generic approach to problem solving and consists of these steps[9]:

1. Identification of a need
2. Definition of the problem (and sub-problems) to be solved
3. Search for necessary background information and data
4. Formulation of objectives and criteria
5. Consideration of alternative solutions to the problem
6. Analyses and evaluations of alternative solutions
7. Decision-making and optimization

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Design has some identifying characteristics. A complicated design problem will usually be broken down into sub-problems, so these can be addressed separately and then considered together in reaching final solutions. Often, design must go forward even when there is missing or unknown information. In design, judgments about the quality of a solution are made by measuring performance against the stated goals, not the other way around. Finally, design is often iterative. There may be a need to design and redesign several times to optimize performance with respect to goals. There may be no perfect solution to a design problem, but instead a compromise solution representing the best solution under conflicting constraints.

Primary implant stability

Primary implant stability is considered to play a fundamental role in obtaining successful osseointegration[10]. Friberg et al[11] reported an implant failure rate of 32% for those implants which showed inadequate initial stability. Major contributors to initial implant stability have been suggested to be implant length, diameter, surface texture, and thread configuration. Initial stability can be significantly less in bones of low density increasing the risk of failure[12]. Although bone density and quantity are local factors and cannot be controlled, the implant design and surgical technique may be adapted to the specific bone situation to improve the initial implant stability[13].

A common factor between early loading and delayed loading of dental implants is the initial stability of the implant, implying that close apposition of bone at the time of implant placement from factors such as bone quality and surgical technique, may be the fundamental criterion in obtaining osseointegration[14,15]. Such "anchorage" of an implant in bone may also be influenced by the implant design with such factors as overall surface area, length and thread configuration. This may be significant when anticipating immediate or early loading in order to reduce micromotion of greater than 150mm.

The following would be the design principles, one would want to achieve through an implant design:

1. Gain initial stability that would reduce the threshold for the 'tolerated micromotion' and minimize the waiting-period required for loading the implant.
2. Incorporate design factors, that would diminish the effect of shear forces on the interface (such as surface roughness related and thread features) so that marginal bone is preserved).
3. Design features that may stimulate bone formation, and/ or facilitate bone healing (secondary osseointegration).

Implant Thread

Threads have been incorporated into implants to improve initial stability[16,17], enlarge implant surface area, and distribute stress favourably[18,19]. It has been proposed that threads, due to their uneven contour will generate a heterogeneous stress field, which will match the 'physiologic overload zone', thus prompting new bone formation[20] which may support the 'cuplike bone formation' at the crest of the implant thread[21]. Thread patterns in dental implants currently range from microthreads near the neck of the implant, to broad macrothreads on the mid-body and a variety of altered pitch threads to induce self-tapping and bone compression [22].

Implant neck (crest module)

The highest bone stresses have been reported to be concentrated in the cortical bone in the region of the implant neck as demonstrated in Finite Element Analysis (FEA) of loaded implants with or without superstructure[23]. It has been suggested that the implant neck should be smooth/ polished, supporting the belief that the crest module should not be designed for load bearing. However, significant loss of crestal bone has been reported for implants with 3 mm long smooth polished necks. Following the placement of an endosseous implant, there is an initial bone modeling/ remodeling during healing and the establishment of a biological seal around the neck of the implant. This bone modeling for biologic seal is a combination of a 1.0-1.5 mm junctional epithelium and a 1.5 - 2.0 mm connective tissue region that is established superior to the alveolar crest. The results of the study by Hansson also supported the concept that an improved mechanical stimulation of the marginal bone can be brought about by providing the neck of the implant with rough elements. Norton evaluated radiographically 33 single tooth implants for up to 4 years and reported significantly lower amounts of bone loss, 0.32 mm mesially and 0.34 mm distally with an implant system that incorporates microthread retention elements at the implant neck.

CONCLUSION

Currently, there is a trend towards using a one-stage non-submerged surgical procedure along with an early/ immediate loading protocol. A close contact between bone and implant may be the essential feature that permits the transfer of stress from the implant to the bone without any appreciable relative motion and thus providing a physiological stress to induce bone remodeling/ modeling.

However, to make it a predictable treatment modality in a low-density bone, considerations should be made to accommodate changes occurring in the establishment of a biologic width and incorporate design features that optimize initial stability and maximize the crestal cortical bone preservation by translating shear strains at the interface to a more compressive component.

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