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Prosthetic Design and Load Considerations on Alveolar Bone — A Laconic Review

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ABSTRACT

For prosthetic therapy to be successful and last a long time, the design and load considerations on the alveolar bone are essential. The prosthetic option selected—removable, fixed, or implant-supported will determine which issues need to be taken into account. To distributing forces uniformly and avoiding undue stress on the alveolar bone, the design must offer sufficient retention and support. Prosthodontists can design prosthetic restorations that maintain the integrity and health of the alveolar bone while simultaneously restoring function and aesthetics by carefully weighing all relevant criteria. This review article aims to discuss various loads falling on the supporting alveolar bone from various prosthetic treatment options.

KEY WORDS: *Alveolar Bone; Prosthetic Design; Stress Distribution; Bone Resorption.*

INTRODUCTION

Any prosthetic procedure should strive to provide the best possible performance, aesthetics, and lifespan while minimising stress on the alveolar bone. By minimising mechanical stress and using suitable materials and prosthetic designs, medical professionals can improve patient outcomes, lower the chance of problems, and stop excessive bone resorption.
The design parameters and load factors that affect the stability and health of the alveolar bone during implant prosthetic therapy will be covered in this scoping review.

I. Design and Load Considerations on Alveolar Bone During Removable Prosthetic Options

In order to stop alveolar bone resorption, proper stress distribution is essential. Compared to tissue-supported dentures, loads are distributed more equally in prosthesis supported by implants. To provide even load distribution, retention, stability, and support must be taken into account during design. To reduce harmful stresses on the alveolar bone, base extension, occlusion, and material selection are all important considerations. Careful consideration of these issues is necessary to guarantee that detachable prostheses do not accelerate bone loss and continue to operate over time.[1]

The longevity of the prosthetic appliance and the condition of the underlying tissues are significantly influenced by the design and load factors placed on the alveolar bone during the usage of removable prosthetic solutions. When removable prosthetics are designed properly, the mechanical stresses are spread as much as possible, reducing discomfort and bone resorption.

Important Design and Load Factors:

1. Stress Distribution and Bone Resorption [1]

After tooth loss, the alveolar bone resorbs naturally over time; incorrect loading from detachable prosthesis accelerates this process. Removable prosthetics with poor design concentrate forces in certain places, which accelerates bone loss. An uniform distribution of masticatory pressures throughout the edentulous ridge is crucial in this situation.

Tissue-supported dentures: These are supported by the surrounding mucosa and alveolar ridge. Localised bone resorption results by applying excessive pressure to certain places, especially in the mandible and maxilla's anterior areas.

Overdentures supported by implants: These can slow down or even stop additional bone resorption by acting as an anchor for the implants, which helps distribute stresses more uniformly throughout the alveolar ridge. [1]

2. Retention, Stability, and Support

Retention (resistance to displacement), stability (resistance to movement during function), and support (distribution of occlusal forces) are the main factors taken into account while designing removable prosthetics. These have an immediate impact on the forces applied to the alveolar bone.

Retention: While clasps in removable partial dentures (RPDs) aid in retention, they may also cause torquing forces on the teeth of the abutment and the alveolar bone that surrounds them. Overload and damage might result from improper clasp design.

Stability: To enhance stability and lessen the strain on delicate bone regions, make sure the denture's base is appropriately extended to cover the majority of the alveolar ridge.

Support: Sufficient support is essential, especially for tissue-supported dentures, since it reduces the load per unit area applied to the alveolar bone.[2]

3. Material Considerations

The load transmitted to the alveolar bone depends on the type of material used in removable prosthesis, whether they are flexible or rigid. Complete dentures are frequently made of acrylic resin. Although it permits some elasticity, the compressive forces it experiences are totally transferred to the bone beneath.

Metal frameworks: Unlike resin materials, metal frameworks (such as cobalt-chromium) used in RPDs have a higher degree of rigidity and may transfer forces in a different way. But when engineered correctly, stiffness gives better load distribution.[3]

4. Implant Overdentures

Because the implants serve as the primary source of support, overdentures retained by implants lessen the strain on the alveolar bone. This method lessens the requirement for large tissue-supported regions that may result in bone resorption and helps preserve bone density around the implants.[4]

5. Design Factors in Overdentures and Partial Dentures

In order to minimise stress concentration on the alveolar bone, proper denture base extension, balanced occlusion, and decreased cantilever effects are essential.

By distributing occlusal stresses bilaterally, balanced occlusion lessens the chance of overloading one side of the prosthesis and the associated alveolar bone.

Base extension: The region of load distribution increases and the overall stress on the alveolar bone is decreased by fully extending the prosthesis' base to include the retromolar pads and tuberosities. [5]

II. Alveolar bone design and stress considerations during fixed prosthetic choices

To guarantee the longevity of the prosthesis and the preservation of bone health, design and load considerations on the alveolar bone during fixed prosthetic choices are essential. In order to distribute occlusal stresses appropriately, fixed prostheses—such as full-arch fixed prosthetics, implant-supported crowns, and fixed dental bridges—need meticulous planning. The intention is to avoid overstressing the alveolar bone, as this may result in bone resorption or failure of the prosthetic parts.

Important Design and Load Factors: [6]

1. Bone Response to Stress Distribution

Load distribution is essential in fixed prosthesis to preserve the alveolar bone's health. Mechanical forces cause the bone to rebuild, so it's critical that the forces are distributed uniformly to avoid excessive resorption.

Fixed prostheses supported by implants: These devices use implants to transfer occlusal loads straight to the alveolar bone. The ability of the surrounding bone to support the implants is crucial, and appropriate implant positioning (depth, angle, and spacing) guarantees that stresses are dispersed uniformly.

Natural teeth-supported fixed prostheses: The abutment teeth and the periodontal structures they are connected to sustain the weight of dental bridges. Tooth mobility, periodontal disease, or bone loss can be caused by inadequate design or overloading of the abutments. [6]

2. Occlusal Load on Cantilevers

It is necessary to reduce cantilever forces in fixed prosthesis design because they can put undue strain on implants and natural teeth. Because cantilevers apply asymmetric loads, they can cause implants or abutments to loosen or resorb bone.

Cantilever bridges: Limiting the cantilever arm's length and making sure that the occlusal forces are channelled down the long axis of the supporting abutments or implants are crucial when utilising a cantilever design. Implant or abutment failure may result from cantilever designs with excessive occlusal load.[7]

3. Implant-to-Crown Ratio

The implant-to-crown ratio has an important impact on the weight transfer to the alveolar bone for implant-supported fixed prosthesis. The tension on the surrounding bone will rise with a tall crown on a short implant because of the increased leverage. Preventing peri-implant bone loss is mostly dependent on reducing stress concentration at the crestal bone level, which is achieved by having an ideal implant-to-crown ratio.

Bone preservation: By placing implants sufficiently deep to produce optimal crown-to-implant ratios, it is possible to reduce micro-movements at the implant-bone interface, which can cause bone loss, and more effectively distribute occlusal loads. [8]

4. Splinting of Prosthetic Units

By splinting several crowns together, you can more evenly distribute the occlusal stresses throughout the prosthesis and lessen the strain on individual abutments or implants. This method works especially well in places where there is a chance of overloading individual implants or where the quality of the bone is low.

Splinting: By preventing an implant or tooth from being overworked, this treatment lowers the risk of implant failure or bone resorption. In full-arch restorations, where stress distribution is more complicated, it is frequently advised. [9]

5. Material Considerations

The materials utilised in fixed prosthetics, whether for the veneering material (ceramic, composite), or for the framework (metal, zirconia, etc.), affect how forces are transmitted to the underlying bone.

Zirconia frameworks: They are highly stiff, which helps to equally distribute pressures but, in certain situations, can cause stress concentration. The amount of peak stress values sent to the alveolar bone can be decreased by the use of shock-absorbing materials, such as softer ceramic layers.

Porcelain-fused-to-metal (PFM) restorations efficiently distribute forces over the supporting components when they are constructed correctly, offering a balance between mechanical strength and cosmetic appeal. [10]

6. Abutment Design and Connection Type

For the best possible load distribution, the prosthetic crown and implant abutment must be connected. At the implant interface, micro-movement that could cause bone loss is reduced by a strong, tight connection.

Platform-switching: This method, in which the implant platform is larger than the abutment, can lessen the strain at the implant neck and, consequently, the amount of bone loss in the crestal region.

Conical connections: These connections improve bone preservation surrounding the implant by providing increased stability and minimising micro-movements between the abutment and implant. [11]

7. Immediate vs. Delayed Loading

Another crucial element is when prosthetic loading occurs on implants. Shortly after implant implantation, immediate loading applies functional loads to the implant and surrounding bone. If the bone-implant contact is not yet solid, there is an increased chance of implant failure and bone loss even though initial loading can be effective with appropriate case selection.

Delayed loading: This method promotes greater bone healing and a stronger bone-implant link by allowing for a period of osseointegration prior to adding masticatory loads. [12]

III. Alveolar bone design and stress concerns during different implant prosthetic options

In order to preserve osseointegration, avoid peri-implant bone loss, and ensure the durability of the prostheses, design and load considerations on the alveolar bone during various implant prosthetic choices are crucial. The alveolar bone is subjected to varying mechanical pressures according on the kind of implant-supported prosthesis used, including overdentures, multiple-unit bridges, single implants, and full-arch fixed prosthesis. For optimal results, occlusal load management and proper design are essential.

Important Design and Load Factors for Implant Prosthetic Alternatives:

1. Single Implant-Supported Crown

A single crown supported by an implant restores a lost tooth by applying direct occlusal stresses to the alveolar bone surrounding it. To prevent overloading, the prosthetic design and implant placement must be done correctly.

Implant Positioning: To guarantee that occlusal forces are transferred vertically into the alveolar bone and minimise lateral stresses that may cause bone resorption, the implant should be positioned centrally along the prosthetic crown's long axis.

Implant-to-Crown Ratio: Excessive leverage pressures are avoided with an ideal implant-to-crown ratio (shorter crowns or suitably lengthy implants). Stress concentration may result from a taller crown's increased bending moments on the implant and bone.[2]

2. Multiple-Unit Implant-Supported Bridge

When replacing two or more lost teeth, a fixed bridge can be supported by several implants. In this case, the way the implants interact with the way the weight is distributed throughout the bridge is crucial.

Splinting Implants: By joining several implants with a fixed bridge, occlusal forces are distributed throughout the prosthetic device as a whole. As a result, the surrounding bone and individual implants are under less stress.

Implant Spacing: To guarantee consistent weight distribution, implants must be spaced appropriately apart. Stress concentration can cause bone loss surrounding implants if they are positioned too closely together or too far apart.[7]

3. Full-Arch Fixed Implant-Supported Prosthesis (All-on-4/All-on-6)

Multiple implants are utilised to support an entire dental arch in full-arch fixed implant-supported prostheses, like the All-on-4 or All-on-6 designs. Because of the wider covering area and range of forces involved, these prostheses require careful consideration in both design and load control.

Angulated Implants: To optimise bone contact and steer clear of anatomical structures like the maxillary sinus or the mandibular nerve, posterior implants in All-on-4 designs are frequently positioned at an angle. Angulation lessens the need for bone grafting by assisting in the more effective distribution of occlusal loads throughout the prosthesis.
Cantilever Length: Preventing an excessive strain on the distal implants requires limiting the cantilever's length, or the prosthesis's extension past the last implant. Implant failure or peri-implant bone loss may result from excessive cantilever forces.[13]

4. Implant-Supported Overdenture
A detachable prosthesis secured by two or more implants is known as an implant-supported overdenture. While the soft tissue also provides support, the overdenture depends on the implants for stability and retention. One important factor to consider is the distribution of load between the implants and the alveolar ridge.
Implant Number and Position: To guarantee even load distribution, the number of implants typically two in the mandible and four in the maxilla as well as their placement are critical factors. When implants are positioned too far anteriorly, the posterior alveolar ridge may experience cantilever stresses that cause bone resorption.
Attachment Type: The load transfer is impacted by the attachment system selection (ball, locator, or bar-retained attachments). Ball attachments may concentrate more strain on specific implants, whereas bar-retained systems more equally distribute loads across the implants and the alveolar bone. [14]

5. Implant-Supported Hybrid Prosthesis
A full-arch restoration screw-retained on several implants is called a hybrid prosthesis. It combines the benefits of removable and fixed prostheses, although it puts more strain on the supporting implants.
Rigid Splinting: The rigid framework used in hybrid prostheses, usually composed of zirconia or titanium, splints the implants together and disperses the masticatory forces across the prosthetic arch. An appropriate framework design avoids bone loading and lessens the concentration of stress on specific implants.
Occlusal Considerations: To provide a uniform force distribution throughout function, balanced occlusion is essential. Inadequate occlusal design may provide lateral stresses that overburden the implants and cause bone resorption around the implants. [15]

6. Immediate vs. Delayed Loading of Implants
The stress applied to the alveolar bone throughout the healing process depends on whether the implants are loaded right away or delayed. Fast loading can result in a more functional and aesthetically pleasing restoration more quickly, but it also puts early stress on the interface between the implant and the bone, which may not be ideal if the bone has not fully healed.
Immediate Loading: Immediately following implantation, forces are delivered to the implants as part of immediate loading protocols. This shortens the duration of treatment, but it necessitates thorough evaluation of the main stability of the implant, the quality of the bone, and the distribution of occlusal stresses. Implant failure may result from excessive occlusal forces or immediate loading in cases of poor bone health.

Delay in Loading: By allowing the bone to osseointegrated and mend around the implants prior to applying force, delayed loading can lower the chance of implant failure or bone loss. But this calls for a lengthier healing time and frequently calls for a temporary prosthesis. [16]

General Design and Load Factors Across Implant Prosthetic Options

Implant Distribution: By spreading implants uniformly throughout the prosthetic arch, stresses are dispersed and the likelihood of localised stress on the alveolar bone is decreased. Bone quality and anatomical landmarks should be considered during installation.
Implant Diameter and Length: Greater surface area for load distribution is provided by longer and larger-diameter implants, which lessens stress on the bone. Implants that are short or narrow may focus stresses on smaller regions of bone, raising the possibility of resorption.
Platform switching can assist lessen stress at the crestal bone level. It entails placing a smaller-diameter abutment on an implant platform with a greater diameter. It has been demonstrated that platform switching reduces the concentration of stress at the implant neck, preserving marginal bone levels. [17]
Occlusal Design In implant prostheses, the occlusal scheme must reduce lateral forces and guarantee that vertical loads are distributed along the implants' long axis. Implant failure and bone resorption can result from severe shear stresses brought on by poor occlusal design. [2]

SUMMARY

The effectiveness of implant-supported prosthetics is greatly influenced by careful planning and execution, which brings us to the conclusion of the design and load considerations on alveolar bone during the various implant prosthetic choices. The ultimate objective is to maintain the integrity and health of the surrounding alveolar bone while assuring the prosthetic restoration's lifespan.
Important lessons learnt:
Stress Distribution: One of the most important ways to reduce the risk of peri-implant bone loss is to distribute occlusal pressures carefully. Reducing concentrated pressures on the alveolar bone in restorations involving single implants, multiple-unit bridges, or full-arch prosthetics requires careful implant placement and alignment with the prosthetic design.
Prosthetic Design: Different prosthetic alternatives necessitate different design considerations. Examples of these possibilities include single crowns, multiple-unit bridges, and full-arch restorations. For example, reducing stress on individual implants in a bridge or hybrid prosthesis can be achieved by splinting many implants together. Preventing excessive loading on distal implants can also be achieved by limiting cantilever extensions.

Implant Features: A more uniform force distribution is facilitated by the size and placement of implants, such as the use of longer or bigger diameter implants. By lessening stress at the implant-bone interface, strategies like platform swapping can aid in the preservation of marginal bone.

Occlusal Load: To reduce lateral forces and guarantee that forces are distributed vertically along the implants' long axis, balanced occlusion is essential in all prosthetic solutions. The likelihood of implant failure and bone resorption is increased by poor occlusal design.

Material and Attachment Considerations: Depending on the clinical situation, prosthetic materials (such acrylic overdentures or zirconia frameworks) and attachment systems (like locator vs. bar-retained attachments) should be chosen to minimise load transmission to the bone.

CONCLUSION

Maintaining healthy alveolar bone and assuring long-term success in implant-supported prosthetics requires careful consideration of design and load management. Clinicians can greatly improve patient outcomes, lower the risk of problems, and stop excessive bone resorption by optimising implant placement, minimising mechanical stress, and choosing suitable materials and prosthetic designs. Following these guidelines guarantees that implant-supported prosthetics maintain the underlying alveolar bone structure while producing long-lasting, useful, and aesthetically beautiful outcomes.

REFERENCES

[1] Carlsson, G. E. (2009). "Critical review of the literature on prosthetic rehabilitation of the edentulous patient." Journal of Oral Rehabilitation.
[2] Misch, C. E., & Perez, H. M. (2008). "Dental Implant Prosthetics." Elsevier Health Sciences.
[3] Zarb, G. A., & Bolender, C. L. (2013). Prosthodontic Treatment for Edentulous Patients: Complete Dentures and Implant-Supported Prostheses. Elsevier.
[4] Raghoebar, G. M., et al. (2014). "Long-term results of bone resorption and dental implants in patients treated with overdentures." Clinical Oral Implants Research.
[5] Preiskel, H. W. (1996). "Overdentures Made Easy: A Guide to Implant and Root Supported Prostheses." Quintessence Publishing.
[6] Brunski, J. B. (1999). "In vivo bone response to biomechanical loading at the bone/dental-implant interface." Advances in Dental Research.
[7] Rangert, B., et al. (1995). "Load factor control for implants in the posterior partially edentulous segment." International Journal of Oral and Maxillofacial Implants.
[8] Kinsel, R. P., & Lin, D. (2009). "Retrospective analysis of implant survival based on relative implant/tooth crown ratios." International Journal of Prosthodontics.
[9] Michalakis, K. X., et al. (2011). "Biomechanical aspects of fixed partial dentures." Journal of Oral Science.
[10] Akça, K., & Cehreli, M. C. (2006). "Biologic and mechanical perspectives of implant biomechanics." International Journal of Oral and Maxillofacial Implants.
[11] Canullo, L., & Fedele, G. R. (2010). "Platform switching and marginal bone-level alterations: the results of a randomized-controlled trial." Clinical Oral Implants Research.
[12] Esposito, M., et al. (2007). "Early vs. delayed loading of dental implants: a Cochrane systematic review." European Journal of Oral Implantology.
[13] Malo, P., et al. (2003). "The 'All-on-4' immediate-function concept with Brånemark implants in the mandible." Clinical Implant Dentistry and Related Research.
[14] Naert, I., et al. (2004). "A comparative evaluation of 2-year implant survival, marginal bone level, and soft tissue health of immediate versus delayed loading of implants in the edentulous mandible." Clinical Oral Implants Research.
[15] Sadowsky, S. J. (1997). "Mandibular implant-retained overdentures: a literature review." Journal of Prosthetic Dentistry.
[16] Esposito, M., et al. (2007). "Early vs. delayed loading of dental implants: a Cochrane systematic review." European Journal of Oral Implantology.
[17] Canullo, L., & Fedele, G. R. (2010). "Platform switching and marginal bone-level alterations: the results of a randomized-controlled trial." Clinical Oral Implants Research.