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Residual Ridge Resorption – Revisited

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1. Introduction

Residual ridge resorption (RRR) is a term that is used to describe the changes which affect the alveolar ridge following tooth extractions, and which continue even after healing of the extraction socket. The most significant feature of this healing process is that the residual bony architecture of the maxilla and mandible undergoes a life-long catabolic remodelling. The rate of reduction in size of the residual ridge is maximum in the first three months and then gradually tapers off. However, bone resorption activity continues throughout life at a slower rate, resulting in loss of varying amount of jaw structure, ultimately leaving the patient a 'dental cripple'.

Rehabilitation of a totally edentulous patient using a conventional complete removable denture is a routine clinical procedure, yet at times it can be a difficult and challenging process. All these patients have been through a period of edentulousness that varies from weeks to months or even years and the promise of having 'teeth' again often makes their expectations unrealistically high. The challenges facing the clinician are therefore manifold and this is the reason why there remains a wide variation in the predictability of clinical success.

Even experienced clinicians know fully well that it is not possible to completely satisfy all the needs of edentulous patients, even with a well-fabricated prosthesis. There is a wide range of variation seen within the community as regards the needs, expectations, and responses to treatment. Before initiating treatment it is therefore, essential that the dental surgeon provide all patients with sufficient information regarding treatment options and the expected outcome of each. This allows them to make adequately informed decisions regarding their needs. The treatment options are to be presented in such a manner that each modality of treatment has a perspective that is relevant to the patient's needs and expectations. It is also imperative that all treatment advice should be in consonance with the clinical findings and physical parameters of the existing oral condition.

2. Residual ridge remodelling

Immediately following tooth extraction, a cascade of inflammatory mediators is initiated, which results in the formation of a blood clot which is the first step in the eventual closure of the extraction wound. The clot then undergoes organisation and is gradually replaced by granulation tissue towards the periphery and base of the alveolar socket. After a span of

seven to ten days, new bone formation is evident, with osteoid matrix present as non-calcified bone spicules. Mineralization progresses from the alveolar socket base in a coronal direction and two-thirds of the socket is filled in approximately 5 to 6 weeks. (Schropp et al, 2003)

The bony remodelling that subsequently takes place occurs in two phases: an initial and fairly rapid phase that can be observed in the first 3 months and the subsequent slow, minimal yet continuous resorption that continues life-long. During the initial period there is new bone formation with loss of almost all of the alveolar crest height and simultaneous reduction of approximately two-thirds of the ridge width. These changes continue over the initial ten to twelve week period. Between six and twelve months, part of the new laid-down bone undergoes further remodelling resulting in the further reduction of the alveolar ridge width until it is reduced to approximately half. The rate of resorption then slows down to minimal levels, yet since it is continues throughout the individual's life there is a significant reduction in bony volume seen in geriatric patients.

This unique phenomenon is known as residual ridge resorption (RRR). The rate of RRR varies, from one individual to another; at different phases of life and even at different sites in the same person. The clinical significance of such remodelling is that the functionality of removable prostheses, which rely greatly on the quantity and architecture of the residual ridge, may be adversely affected.

Residual ridge resorption is often clinically evident yet the actual physiological changes that follow tooth extraction are not well-understood. Atwood first postulated the four main factors namely anatomic, prosthetic, metabolic, and functional factors that are responsible for the loss of alveolar bone. (Atwood, 1957, 1962) Since then, numerous investigators have made an attempt to analyse the changes in the form of the residual alveolar ridge using lateral cephalograms, panoramic radiographs, or diagnostic casts as standardized measurements. (Carlsson & Persson, 1967) The main aim of these investigators was to isolate the factor or factors that could explain a pathologic origin in severe cases of RRR. Despite best efforts, till date, no study has been able to conclusively provide evidence to any one factor or causative agent. What is clinically proven is that the use of ill-fitting removable prostheses, which generate localised mechanical stress onto the alveolar bone affect the rate of bone loss of residual ridges. Among the other systemic causes, only postmenopausal osteoporosis has been shown to have a cause-effect relationship with RRR. (Kribbs, 1990, Nishimura et al, 1992) Since residual ridge resorption exhibits such a wide variation in its clinical presentation it can be reasonably assumed that a myriad of factors all play a part in determining the ultimate rate and extent of bone loss in a particular individual.

3. Factors affecting resorption of the residual ridge

3.1 Anatomic factors

It is postulated that RRR varies with the quantity and quality of the bone of the residual ridges. Thus it is likely that the more bone volume there is, more the quantum of resorption will be seen. Another anatomic factor that is crucial to an increased rate of resorption is the bone density of the ridge. However, it is important to remember that the

density at any given moment does not indicate accurately the current metabolic status of the ridge and that osteoclastic activity will resorb the bone irrespective of the degree of calcification.

3.2 Localised mechanical stress from removable prostheses

Kelly first described the "combination syndrome" wherein patients with remaining mandibular natural teeth against a maxillary complete denture were shown to have an exaggerated loss of anterior segment of maxillary residual ridge. (Kelly, 1972) Carlsson and others conducted a prospective clinical study on a group of partially edentulous patients. Cases of Kennedy Class I edentulous situation were studied under three groups; the first without any mandibular denture, second were those wearing partial denture with bilateral free-end saddles, and the third group were those having a partial denture with anterior lingual bar. The results of the study revealed an increased rate of RRR of the edentulous ridge in the groups wearing dentures for prolonged periods. (Carlsson, 1967) It was assumed that excessive mechanical stresses were responsible for the increased degree of resorption, as greater loss of residual ridge volume was observed in patients who wore their dentures for long hours as compared to the edentulous ridges of the patients who wore their dentures less frequently.

3.3 Stress and strain effect

It is well known that osteoid tissue that receives constant mechanical stimuli maintains a balance between osteoclastic and osteoblastic activity. When bone is in a state of immobilization or a weightless environment, the reduced mechanical stress cannot sustain the normal remodelling process which results in a decrease of calcified bone mass which is known as disuse atrophy. On the other hand, it has been demonstrated physiologically that applied mechanical force can stimulate bone apposition. The oral and facial musculature during functional jaw movements such as mastication, swallowing, produce forces on the occlusal surface of artificial teeth, which is transmitted via the denture base to the underlying residual ridge. Removable partial or complete dentures which are primarily 'tissue-borne' transmit the stress through the mucosa directly to the residual ridge, making it the primary stress bearing area.

3.4 Role of inflammatory mediators

Various inflammatory mediators, mainly prostaglandins, have been regarded by many workers as playing a role in increasing the rate of residual ridge resorption. A study by Yeh and Rodan (1984) showed that when osteoblastic cells were subjected to repetitive mechanical stresses in-vitro there was a significant increase in prostaglandin E2 synthesis. In a separate study that used edentulous rats, the daily administration of indomethacin, an inhibitor of cyclooxygenase (an enzyme required for the prostaglandin synthesis), reduced the rate of RRR to 50% within the experimental period. When systemic delivery of prostaglandin E2 was initiated the inhibitory effect of indomethacin was reduced thus leading the investigators to believe that this could be one factor that could mediate the residual ridge bone resorption activity.(Nishimura et al, 1988) The cause-effect direct relationship between prostaglandin-mediated bone resorption, resulting in severe form of RRR, and the stress related resorption of the residual ridge

has not been successfully demonstrated. (Devlin & Ferguson, 1991) The synthesis of certain biologically active substances by the edentulous mucosa may play a role in enhancing osteoclastic activity of residual ridge alveolar bone, but these are yet to be identified.

3.5 Osteoporosis and post-menopausal osteoporotic changes

The extent of RRR is proportional to the time lapsed after the teeth have been extracted as well as the age of the patient. (Humphries et al, 1989) Osteoclastic activity occurs primarily on the surface of the residual ridge and hence there is a three-dimensional change in the shape of the ridge. The maxillary residual ridge has been reported to be significantly smaller in postmenopausal osteoporotic women while their edentulous mandible remained the same as the age related controls. (Kribbs, 1990) When bone resorption occurs at the labial and lingual surfaces of the residual ridge in preference to the occlusal surface the result is a knife-edged ridge. Studies have exhibited that postmenopausal women with lower bone densitometric scores showed a tendency to have a knife-edge lower alveolar ridge. (Nishimura et al, 1992) This may occur in combination with a small maxillary ridge which may be a disadvantage to successful rehabilitation using a conventional removable prosthesis. Histological studies of residual ridges indicate that extraction sockets heal with active synthesis of trabecular bone. Trabecular bone formation is seen around the borders of post-extraction socket and the large amount of bone resorption due to osteoclastic activity occurs towards the crestal region. This often results in a distinctive porosity on the crest of the residual ridge alveolar bone. (Araújo & Lindhe, 2005)

4. Differential resorption rate in maxilla and mandible

It is a clinically acknowledged fact that the anterior mandible resorbs 4 times faster than the anterior maxilla. The probable reasoning for this fact are difference in the square area of the maxilla and the mandible; the property of the mucoperiosteum that has a 'shock absorber' effect and the variation in the quality of bone of the two jaws.

Woelfel et al have cited the projected maxillary denture area to be 4.2 sq in and 2.3 sq in for the mandible; which is in the ratio of 1.8:1. If a patient bites with a pressure of 50 lbs, this is calculated to be 12 lbs/sq in under the maxillary denture and 21 lbs/sq under the mandibular denture. The significant difference in the two forces may be a causative factor to cause a difference in the rates of resorption. (Woelfel et al, 1974, 1976) The mucoperiosteum due to its 'spongy' nature has a 'dampening effect' on the forces that are transmitted to the alveolar ridge. Since the overlying mucoperiosteum varies in its viscoelastic properties from patient to patient and from maxilla to mandible, its energy absorption qualities may influence the rate of RRR.

Cancellous bone is ideally designed to absorb and dissipate the forces it is subjected to. The maxillary residual ridge is often broader, flatter, and more cancellous than the mandibular ridge. Trabeculae in maxilla are oriented parallel to the direction of compression deformation, allowing for maximal resistance to deformation. The stronger these trabeculae are, the greater is the resistance. These anatomical variations may result in the observed differences in the RRR of the upper and lower jaw.

5. Importance of reducing ridge resorption

Every clinician is aware that the proportions of the residual ridge are critical to denture success, and so it is vital to preserve the dimensions of the post-extraction ridge. There will be a significant decrease in patient morbidity if all attempts are made to maintain its ideal vertical and horizontal proportions instead of reconstructing it at a later date. (Darby et al, 2009) Therefore, any technique that ensures the preservation, augmentation or reconstruction of the alveolar ridge height, thickness and quality, immediately after dental extraction, either with bone regeneration procedures or with the placement of endosseous implants, must be carried out for the maintenance of its vertical and horizontal dimensions. This would very often diminish the need for complex procedures such as augmentation with bone grafts and increase the success of the final prosthesis. (Aimetti et al, 2009; Lekovic et al, 1998)

Several methods have been suggested to facilitate bone formation in freshly extracted sockets, thus minimizing the loss of bone height and buccolingual width. These include guided bone regeneration, with or without grafting material, grafting with bone substitutes, osteogenic materials, such as autogenous bone marrow and plasma rich in growth factors (PRGF); and other biomaterials. (Fiorellini et al, 2005; Mardas et al, 2011; Serino et al, 2003, 2008) The grafting materials used as bone fillers after tooth extraction provide mechanical support and prevent the collapse of both the buccal and lingual bone walls, thus delaying residual ridge resorption and remaining in the place until new bone formation. The ideal bone substitute should be both osteoinductive and osteoconductive in nature, stimulating and serving as a scaffold for bone growth.

6. Surgical options for highly resorbed ridges

Whenever there is significant loss of alveolar bone volume and associated mucosa, the functional and esthetic potential of the prosthesis is severely compromised and patients are often resigned to the fact that they can never be able to function with a removable prosthesis. In recent years the advent of suitable augmentation methods and materials as well as the ability to regenerate maxillary and mandibular bone and soft tissue with subsequent placement of implants has brought new hope to these former 'dental cripples'. (De Coster et al, 2011, Iasella et al, 2003) When there is severe ridge resorption, alveolar distraction osteogenesis can facilitate a substantial amount of both hard and soft-tissue regeneration. Alveolar distraction may be followed by implant placement and prosthetic rehabilitation. Augmentation of the intended implant site makes it possible to achieve an aesthetically acceptable and functional prosthetic restoration. (McCarthy et al, 2003)

In the maxilla, advanced bone resorption may result in pneumatization of the maxillary sinus and subsequent decrease in the height and width of the alveolar bone of the maxilla. In such cases, different grafting techniques such as sinus lift osteotomies followed by onlay grafting can achieve aesthetic and functional restorations. (Branemark et al, 1984; Summers, 1994; Tatum, 1986) Another treatment alternative is alveolar distraction osteogenesis. The concept of distraction osteogenesis was first demonstrated by Ilizarov as a means of lengthening long bones. The procedure is based on the theory of bone distraction along a vector that is transverse to the long axis of the bone, which results in

bone formation. (Ilizarov, 1989) It was later applied to the human mandible, and more recent clinical reports have shown that alveolar distraction osteogenesis is effective for treating severe forms of alveolar ridge atrophy. (Chin & Toth, 1986) A primary advantage of distraction osteogenesis is that there is no need for additional surgery at the donor site. Another benefit is the coordinated lengthening of the bone and associated soft tissues. The alveolar bone in the anterior maxilla is one of the sites in the dental arch where distraction osteogenesis is used with encouraging results. (Aragon & Bohay, 2005; Gaggl et al, 2000; Uckan et al, 2002) The vertical height of the residual ridge may be increased using this technique with subsequent implant placement and rehabilitation using overdentures.

7. Prosthodontic principles to reduce RRR

Certain general principles must be kept in mind during fabrication of complete dentures which will help to reduce the stress transmission and help preserve the alveolar ridge. This may be achieved by having broad area of coverage under the denture base (to reduce the force per unit area). A decrease in the number of denture teeth; decrease in the buccolingual width of teeth; improved occlusal tooth design form (to decrease the amount of force required to penetrate a bolus of food) are some of the other techniques that may also be used. During tooth setup the aim should be to reduce the number of inclined planes (to minimize dislodgement of dentures and shear forces) and achieve a centralization of occlusal contacts (to increase stability of dentures and to maximize compressive load). Accurate recording of maxillomandibular relationship will ensure optimum vertical rest dimension which will decrease the frequency and duration of tooth contacts, thereby giving adequate rest to the underlying ridges. (Kapur & Soman, 1964; Van Waas, 1990)

8. Prosthodontic rehabilitation of resorbed ridges

8.1 Conventional complete dentures

For many decades complete tissue-supported removable prostheses have been regarded as the treatment of choice for edentulous patients. The primary reason for this was the absence of a viable alternative. The treatment outcome of rehabilitation with complete dentures cannot be predicted, and it is a common clinical experience that there is a wide variation in the patient response to this treatment modality. Despite the fact that complete dentures are known to have poor masticatory capability, patients seem to accept this as part of the ageing process. Clinically the commonest reason in patients reporting for treatment is the 'loosening' of the dentures – which is often due to the continual resorption of the alveolar ridge. The expectations of clinicians seem to be different from than that of the patients when it comes to evaluation of removable complete dentures. Though the clinician may not be satisfied for a variety of reasons it is the patients who seem to be generally happy with conventional dentures. Despite all the controversy, for the appropriate age and oral condition, general health, and socioeconomic status, a carefully fabricated complete removable denture may be a safe, predictable, and cost-effective treatment to restore an edentulous patient, especially in developing countries.

8.2 Implant supported overdentures

The field of prosthodontic rehabilitation has been irreversibly transformed with the advent of osseointegrated titanium implants. The predictable clinical success of osseointegrated implants has ensured that the concept of an implant-supported prosthesis as a reliable protocol in the management of complete edentulism is now accepted world-wide. The evolution of implants as a means of ensuring support, retention and stability of an implant retained overdenture have revolutionised the treatment concepts and should be made the treatment of choice, wherever possible. In most cases there is improved stability, greater functional efficiency, and improved levels of patient satisfaction with the implant-retained and tissue-supported mandibular overdenture, as compared to the conventional removable dentures.

In the developed countries a mandibular 2-implant retained overdenture treatment modality is, by and large, considered the 'gold standard' for the treatment of the edentulous mandible. This is based on the efficacy of this treatment modality as regards function, nutrition, and overall quality of life, balanced with patient preferences and expectations, treatment planning, prosthodontic management, and predicted costs. In lesser developed nations, however, the cost factor for such treatment over conventional dentures appears to be the only area of concern regarding its acceptability among all practitioners. Though, it is generally agreed that, when all other treatment options have failed, the only recourse is to use implant-supported overdentures for the management of the edentulous patient with an advanced degree of ridge resorption. The cost versus performance benefit for these two modalities of prosthodontic treatment should be employed by practitioners to facilitate their patients to make informed choices. There is the distinct possibility that with the increasing competition and marketing strategies adopted by the implant manufacturers, the cost of such implants will be sufficiently lowered for them to become affordable across the economic spectrum of patients. This will make implant supported prostheses a realistic option to rehabilitate all patients with poor ridges effectively and economically.

9. Conclusion

The ultimate aim of a successful prosthesis is stability in function and excellent esthetics. The expectations of edentulous patients are highly variable and therefore the outcome of patient treatment varies significantly from one individual to another. The overall degree of patient satisfaction is influenced by social and cultural influences, financial resources, and adaptive capability. A host of other socioeconomic, regional, cultural, age, and gender influences, educational background, knowledge and experience of the clinician play a vital role in the patient acceptance of a particular treatment modality. In the light of present day understanding of the sequelae of residual ridge resorption it is imperative for all clinicians to allow their patients to be partners in making informed treatment choices. The patients should be educated regarding the type and extent of treatment that is ideal for them, the prognosis of the treatment outcomes with various types of removable or fixed prostheses and the alternatives that are available. The end result will be the successful rehabilitation of an increased number of edentulous individuals and many more satisfied clinicians.

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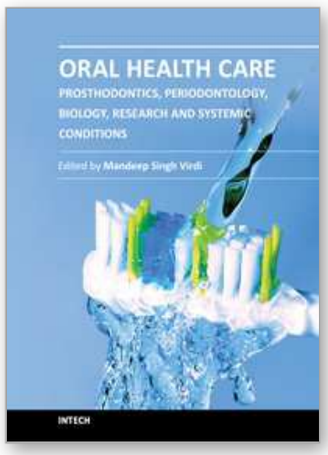
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Geriatric dentistry, or gerodontics, is the branch of dental care dealing with older adults involving the diagnosis, prevention, and treatment of problems associated with normal aging and age-related diseases as part of an interdisciplinary team with other healthcare professionals. Prosthodontics is the dental specialty pertaining to the diagnosis, treatment planning, rehabilitation, and maintenance of the oral function, comfort, appearance, and health of patients with clinical conditions associated with missing or deficient teeth and/or oral and maxillofacial tissues using biocompatible materials. Periodontology, or Periodontics, is the specialty of oral healthcare that concerns supporting structures of teeth, diseases, and conditions that affect them. The supporting tissues are known as the periodontium, which includes the gingiva (gums), alveolar bone, cementum, and the periodontal ligament. Oral biology deals with the microbiota and their interaction within the oral region. Research in oral health and systemic conditions concerns the effect of various systemic conditions on the oral cavity and conversely helps to diagnose various systemic conditions.

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