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REVIEW

Assessment of stress distribution and displacement of complete dentures on flabby ridge with multiple occlusion schemes using finite element analysis

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Keywords: Displacement of complete denture, Finite element analysis, Flabby ridges, Occlusion schemes, Stress distribution.

ABSTRACT

Loss of teeth and supporting tissues, which are functional components of the stomatognathic system, significantly affects masticatory function. Flabby ridges are one of the soft tissue anomalies in the edentulous. The main choice of treatment for edentulous patients with flabby ridges issues is a complete denture (CD). Flabby ridges cause problems with the retention and stabilization of the CD which causes displacement of the denture base during function. Lingualized and linear occlusion schemes were used to overcome the stabilization of CD by reducing stress distribution in the flabby ridge area when obtaining masticatory load. Assessment of stress distribution and displacement of CD can be analyzed using Finite Element Analysis (FEA). This paper describes the use of FEA to assess the stress distribution and displacement of CD on flabby ridges by simulating axial and oblique forces in lingualized and linear occlusion schemes. The use of FEA for assessing stress distribution and displacement of CD in flabby ridges with multiple occlusion schemes has advantages in terms of accuracy and flexibility. (IJP 2024;5(1):1-5)

INTRODUCTION

The stomatognathic system is a complex system with several functional components that work together. Stomatognathic components consist of teeth, bones, joints, ligaments and other supporting tissues.[1] According to the Glossary of Prosthodontic Terms, the stomatognathic system is a combination of several structures involved in speech, mastication, swallowing, and parafunctional functions.[2] Disruption one of the functional components of the stomatognathic system, such as tooth loss, will affect masticatory function, impacting quality of life and nutritional intake. Demographic data on the elderly population indicate demand to rehabilitate edentulous patients has remained high for decades.[3] According to the 2018 National Basic Health Research Report, the proportion of edentulous cases is 2.6 percent for people aged 55 to 64, and 9 percent for people aged 65 and up.[4] Edentulous rehabilitation with complete dentures (CD) is generally considered acceptable because it provides the desired aesthetics as well as occlusal support for mastication and allows the patient to speak normally.[3,4]

The use of CD on flabby ridges will affect retention and stabilization. Flabby ridge is a condition in which the alveolar ridge is easily moved due to bone replacement with fibrous tissue. It is most common in the maxillary anterior, especially when the mandible still has natural anterior teeth and the maxillary ridge is weak underpressure from the mandibular anterior natural teeth.[5,6] The amount and pattern of pressure applied to the oral mucosa is an important aspect of denture treatment that affects CD stabilization and retention.[7] One method for achieving CD retention and stabilization is to use a lingualized and linear occlusion scheme, which aims to achieve an even stress distribution and reduce the occurrence of displacement in the CD.[3,8,9] The number of occlusal contacts was significantly reduced with the lingualized and linear occlusion schemes compared to the conventional occlusion scheme. The masticatory pressure applied to the mandibular alveolar ridge with this occlusion scheme is directed towards to

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Figure 1. Lingualized occlusion.

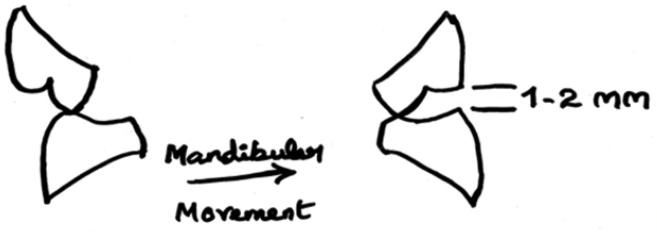

Figure 2. Lingualized occlusion during lateral movement.

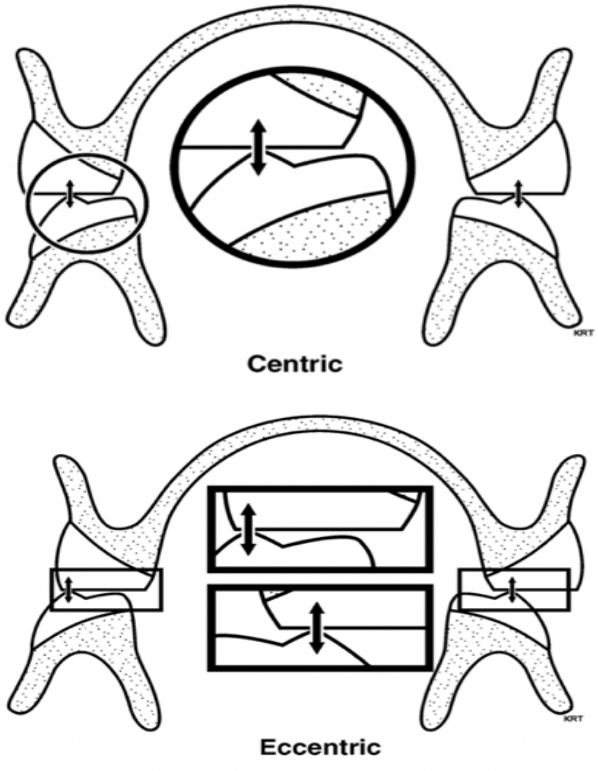

Figure 3. Linear occlusion in centric and eccentric relations.

the center of the ridge, increasing the stability of the mandibular denture and avoiding crossbites.[10]

Finite Element Analysis (FEA) is an important research tool in dental research for biomechanical analysis. This method has the advantages of being non-invasive, allowing visualization of overlapping structures, and allowing the determination of material properties of anatomic craniofacial structures. This method can determine the magnitude, location, and direction of an applied force in addition to assign theoretically measurable stress points. Furthermore, because it has no effect on the physical properties of the material being analyzed, it can be repeated as many times as necessary.[11] The use of FEA is expected to improve understanding of the stress distribution and displacement of complete dentures with flabby ridge in different occlusion schemes.[7,12]

LITERATURE STUDIES

The Effect of Edentulus on Mastication

Definition

According to the Glossary of Prosthodontic Terms, mastication is the process of chewing food for swallowing and digestion.[2,13] The masticatory system is a complex and interconnected system of muscles, bones, ligaments, teeth, and nerves.[14] Masticatory performance is affected by factors such as the number of natural teeth, occlusal strength, and tongue pressure.[15] It is known that the number of teeth below 20 teeth can affect the efficiency, performance and masticatory ability.[13]

Flabby Ridges

According to the Glossary of Prosthodontic Terms 9 (GPT) flabby ridge is defined as excessive movable tissue.[2,17] Historically, the flabby ridge in the maxillary anterior region was a feature of the 'combination syndrome' as identified by Kelly in 1972. The combination syndrome occurs in patients with full maxillary edentulous antagonizes the mandibular Kennedy Class I partial dentition.[5,18]

Flabby ridges caused by uncontrolled tooth extraction, excessive occlusal load on the residual maxillary ridge, unstable occlusal relationships, and flabby tissue often accompanied by atrophic and knife edge ridges.[17,19] The mucosa of the flabby ridges is highly mobile and loses its attachment to the periosteal tissue that covers the bone. Flabby ridge provides limited support for CD. Masticatory pressure can cause displacement of the denture and loss of peripheral seal.[17]

Flabby Ridges Classification

Stefanescu C et al. classify the flabby ridges as follows:[19]
By location: Upper frontal edentulous ridge (very often); Upper fronto-lateral edentulous ridge (often); Maxillary tuberosity (rare); Lower frontal edentulous ridge (very often); Lower fronto-lateral edentulous ridge (rare); Retromolar pad (often).

Based on the structure: Hyperplasic, keratinized, with high antero-posterior and supero-inferior thickness; Atrophic, thin, small antero-posterior thickness and increased supero-inferior length; Apparently histological normal appearance at inspection, but with increased mobilityin all directions.

Flabby Ridges Management

Various managements of flabby ridges have been proposed,

both surgical and non-surgical procedures. Surgical procedures to remove flabby ridges include pre-prosthetic treatment. Surgical procedures on a flabby ridge usually result in the loss of a portion of the vestibular area which can affect the stability of the denture. Either a ridge augmentation procedure using bone graft or platelet rich fibrin (PRF) can be performed but the prognosis is questionable. The implant procedure may also be considered as part of the flabby treatment plan. However, both augmentation and implant procedures have many factors to consider, such as patient age, history of systemic disease, surgical risks and complications, and implant failure.[9,19]

Non-surgical management is a prosthodontic approach. In the principle of prosthodontics, of course, the use of an unfavorable ridge is still better than nothing. The treatment of flabby edges with various printing methods and materials is frequently discussed in various literatures.[19] Determining the best occlusion scheme is also important for achieving denture stability in cases of flabby ridges. Lingualized and linear occlusion are frequently used to maximize the stability, esthetics, and function of the CD in cases of severe alveolar ridge resorption and flabby ridges.

Occlusion Scheme

The occlusal scheme is defined as the shape and arrangement of the occlusal contacts in natural teeth and dentures. The occlusal scheme determines the pattern of occlusal contact between opposing teeth during centric relation and the functional movement of the mandible The amount and direction of the force transmitted through the denture base to the residual ridge is determined by the quantity and intensity of this contact. That is why the occlusal scheme is an important factor in the design of complete denture prostheses. [20] Over the years a number of occlusion concepts have been developed for complete dentures. The main goal is to keep the load on the bone within physiological limits. Lingualized and linear occlusion are the two most popular occlusion schemes for complete dentures with flabby ridges.[21]

Lingualized Occlusion

This concept was introduced by Alfred Gysi in 1927 and SH Payne in 1941: 'cusp-to-fossa occlusion' and Pound: 'lingualized oclusion'. Lingual occlusion can be defined as, a form of denture occlusion in which the maxillary lingual cusp articulates with the mandibular occlusal surface in centric working and non-working side mandibular positions (Fig.1). [8,20,22] Indications of a lingualized occlusion scheme are severe alveolar resorption, class II jaw relations, complete dentures on flabby ridges againts removable partial dentures and patients with parafunctional habits. Aesthetic results can be achieved by anchoring the anatomical upper posterior teeth in lingual occlusion. During lateral movement, the contact that occurs on the working side is only between the lingual cusps of the maxillary and mandibular posterior teeth, on the balancing side there is contact between the palatal cusps of the upper denture and the lingual inner curve of the buccal cusps of the lower denture, as occurs in the conventional concept of occlusion (Fig.2).[22,23]

Advantages of Lingualized occlusion

The vertical force of masticatory pressure is concentrated at the mandibular ridge; Cusp shape is more aesthetic than non-anatomical tooth shape; It can be used in patients with various conditions; Better food bolus penetration; Additional stability is obtained during parafunctional movements with balanced occlusion; It is easier to adjust the occlusion; Can be used in Class II, Class III, and crossbites.[23]

In general, it can be said that there are no contraindications to the use of lingualized occlusion. This occlusion scheme is used in patients who expect esthetics but minimize pressure during mastication and parafunctional movements as a result of severe ridges resorption and flabby tissue or abnormal jaw relationship and large spaces between the ridges.

Linear Occlusion

The occlusal adjustment of the denture was made on the basis of a horizontal plane without anterior overlap (overbite = 0) using the maxillary posterior denture elements with nonanatomical occlusal surfaces and in contact with the occlusal surfaces of the mandibular posterior denture elements which had a straight, long and shaped shape. narrow occlusal surface resembling a line (Fig.3).[3,20]

Linear occlusion consists of the following basic parameters; Zero-degree teeth (flat plane) are in line with the bladed teeth (line contact) where the blade is in a straight line just above the crest of the ridge; The maxillary teeth are arranged in a monoplane with relation to the occlusal plane; There was no interference with the anterior teeth during protrusive or lateral movements.[24]

According to Gronas and Stout, linear occlusion has the potential to generate the smallest lateral forces. In linear occlusion, the bladed teeth are placed on the jaw that requires the most stability. Because the lower jaw usually requires denture stability, the blade teeth in this occlusion scheme are placed on the lower jaw. In the centric and eccentric relation, the occlusive force between the blade teeth and the zero degree teeth occurs in the vertical direction (Fig. 3). The location of masticatory pressure on the mandible does not change significantly in different occlusion positions. Because there is little contact area between the plane and the blade teeth, denture displacement is reduced due to low frictional resistance.[24]

Stress Distribution and Displacement

Dentures depend on the mucosa and residual ridges for support, so it is critical to minimize excessive residual ridge resorption by distributing the occlusal load evenly. In the absence of natural teeth, mechanoreceptors and proprioceptive functions are maintained through continuous stimulation of the denture base and oral mucosa. As an outcome, the pattern of intraoral pressure within the oral cavity is determined by acceptable functional behaviors like mastication, swallowing, and speech, as well as parafunctional behaviors like bruxism.[7]

Mucosal capacity continuous load from denture is a variable that depends on the level and duration of mechanical load during denture wear, there is limited knowledge about the physiological parameters for oral mucosal pain threshold. In particular, the Pressure Pain Threshold (PPT), is a major area of concern in denture treatment because it is the maximum pressure before pain is experienced by the patient.[7] The pressure pain threshold (PPT) in the lower edentulous area was reported to be 630 kPa.[12]

Occlusal forces in the range of 65-110 N, generated on premolars and molars, have been shown to be sufficient to pro-

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cess most foods.[25] The masticatory efficiency depends not only on the stability of the denture but also on the compression of mastication against the mucosa under the denture. Chewing and swallowing as the most frequently performed activities tend to occur in a vertical direction.[6] However, movement in the lateral or oblique direction has the most damaging effect due to displacement of the denture so that the masticatory load is distributed unequally over the entire supporting tissue, with the area receiving greater stress than the other areas.[12]

Alveolar bone resorption will occur at an unpredictable rate after natural teeth are extracted and will severely destabilize the complete denture if the alveolar ridges move excessively (>2 mm) or are of a soft consistency under light stress.[26] In mandibular dentures there is a large displacement of the mucosa during the transmission of masticatory pressure especially when oblique forces are applied in relation to the occlusal surface. Denture displacement is kept to a minimum during the masticatory process by using an appropriate occlusion scheme. Clinical trials have shown that denture displacement increases with the size of the food piece.[12]

Transmission of occlusal forces in mastication is only possible if the mandibular denture is in a stable condition when in contact with the maxillary denture on the non-working side. During in vivo studies of the masticatory process, significant denture displacements have been reported up to 1 mm, despite the articulations being balanced. Stabilization is achieved by various occlusion schemes selected by the dentist according to the intraoral situation.[12]

Finite Element Analysis (FEA)

Finite element analysisis a numerical method to get a solution to a problem accurately by analyzing modeling simulations.[27]

The advantages of using FEA: Modeling and treatment can be free-form according to the preferences of the researcher; Mesh modeling is a combination of several elements; Processing can be done in one program; The original structure and the model have identical conditions.

Studying the stress distribution due to this occlusal configuration is important to understand the phenomenon of load transfer not only but also to improve denture design. Available methods for studying stress analysis include photoelasticity, finite element analysis (FEA), and strain measurement. The application of FEA to assess the biomechanical properties of dentures, bones and teeth has grown rapidly over the last decade as it offers the ability to model complex geometries, evaluate internal stress states of various components and other mechanical quantities. FEA is also very effective for comparison studies where one can examine the effects of one or more parameters of interest through simulation without the need to create multiple physical constructs or prototypes.[28]

DISCUSSION

According to Pai et al flabby ridges can be defined as movable soft tissue located in the superficial area of the alveolar ridge.[29] The flabby ridge mainly occurs when the edentulous ridge is opposed to the natural teeth and is considered a feature of the combination syndrome when it occurs in the anterior maxilla (Lynch and Allen, 2004; Kelly, 1972).[26] Flabby ridges are easily displaced under occlusal forces due to poor support, resulting in impaired denture retention as a consequence of loss of peripheral seal (Pai et al. 2014).[29]

According to MacEntee, support for CD is significantly impaired if the flabby ridges has a displacement of more than 2 mm under masticatory forces.[30] According to a study (Chong 1983), displacements on the working side and balancing side can reach as high as 1.4 and 1.6 mm, respectively. The balancing side shows a marked tendency to dislodge and slide on the foundation (Miyashita et al. 1998) where this displacement occurs under masticatory loads.[25] The use of lingualized and linear occlusion schemes is indicated for flabby ridges because vertical forces are directed more concentrated on the mandibular alveolar ridge, which provides more stability to the denture.[10]

Abduo's (2013) systematic review concluded that bilateral balanced or lingualized occlusion schemes were equally acceptable to patients in terms of mastication, aesthetics, comfort, and speech processing. Improved denture quality significantly affects masticatory performance, occlusal strength and patient satisfaction.[31] Based on the research results, Hasan A et al (2015) consider the two most functionally efficient occlusion schemes, namely lingual and linear occlusion. In the lingualized occlusion scheme, the premolars and molars were arranged and modified so that only the lingual cusps of the maxillary posterior teeth were in contact with the central fossa of the mandibular posterior teeth. The linear occlusion scheme was defined as the pin-point contact of the cusp tips of the bladed mandibular teeth against the maxillary teeth that had no cusps.[22]

According to Fatihallah A, the tension generated in the lingualized occlusion scheme is much less than that produced in the bilateral balanced occlusion scheme, this may be because the number of occlusal contacts is reduced so that there is only one centric stopper between the upper and lower antagonist teeth in the case of the lingualized occlusion scheme.[32] The clinical study conducted by Hameed et al. it was found that based on the results of the radiographic evaluation, linear occlusion resulted in less resorption of the alveolar ridge than lingualized occlusion.[21]

The FEA study conducted by Hasan A (2015) showed that the maximum stress of the linear occlusion scheme was 365 MPa, 62% higher than the lingualized occlusion scheme (224 MPa) in the overdenture implant. A similar pattern was observed in the denture and tooth bases; the linear occlusion scheme resulted in a higher von-mises stress (189 MPa) than the lingualized occlusion scheme (124 MPa).[21] On the other hand, the stress distribution analysis with FEA conducted by Hasan M showed that in dentures, the maximum and minimum stresses for bilateral balanced occlusion and lingualized schemes were not significantly different.[28]

Zmudzki J et al. conducted an FEA study on the distribution of denture stress on the mandible with a load of 100 N in the vertical direction and 141 N in the 45° oblique direction with direct contact and delayed contact on the non-working side.[12] As a result, the direction of the oblique load provides greater stress distribution and displacement, especially on the non-working side with delayed contact. Quantitative assessment of the stress distribution and displacement of the denture showed that the occlusion scheme has an important role in maintaining the stability of the CD under stress despite good adaptation of the CD base and mucosa and shape of the ridge. There has been no research on the stress distribution and CD displacement on flabby ridges on various occlusion schemes, so more research is required.

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CONCLUSION

FEA can be used effectively to assess the stress distribution and displacement of complete dentures on the flabby ridge with lingualized and linear occlusion schemes. Lingualized and linear occlusion schemes on flabby ridges can increase denture stabilization because occlusal forces are more concentrated on the ridges so that they can be distributed well and also reduce horizontal force during eccentric movement due to minimal occlusion contact, reducing CD displacement on the flabby ridges.

SUGGESTIONS

There has been no research on the stress distribution and CD displacement on flabby ridges on various occlusion schemes, so more research is required.

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