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REVIEW

Analysis of Stress Distribution on Knife-Edge with Various Occlusion Schemes Using

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ABSTRACT

Edentulism is an oral health problem that has an impact on quality of life because it causes a loss of balance in the stomatognathic system with disruption of mastication. The impaired masticatory function can be exacerbated from knife-edge conditions, thus the masticatory load received by the mucous in the form of stress distribution becomes greater. One of the efforts to reduce stress concentration is to modify the occlusion concept and anatomical shape of the artificial teeth. However, measuring the stress distribution on edentulous mucous with various occlusion schemes was difficult with in vivo and in vitro tests due to inability to represent the complex system of stomatognation. In silico test with A) can be a solution because the modeling simulation is obtained from CT-scan or digital design. This paper discusses the stress distribution analysis on knife-edge condition with various occlusion schemes using FEM. Stress distribution that exceeds the mucous pressure-pain threshold during denture function will cause poor mastication performance. This paper discusses the analysis of stress distribution under knife-edge ridge conditions with various occlusion schemes using FEM. Stress distribution that exceeds the mucous pressure-pain threshold during denture function will cause poor mastication performance. The use of Lingualized or Monoplane occlusion schemes can be a solution because they use semi-anatomical and non-anatomical artificial teeth to reduce the load passed on the cusp and also minimize resistance during lateral movement. The advantages of FEM in obtaining accurate modeling and flexibility in testing allow analyses that are difficult to perform in in vivo and in vitro, FEM measure stress distribution and its relationship with pain on knife-edge ridge base on various occlusion schemes in complete dentures. (IJP 2024;5(2):111-115)

Introduction

The Stomatognathic System is composed of static structures (mandibular, maxilla, dental arches, TMJ and hyoid bone) and dynamic structures (masticatory, supra and infrahyoid muscles and tongue, lips and cheek muscles) that act together[1] as they are balanced and controlled by the central nervous system performing the stomatognathic functions: suction, breathing, swallowing, speech and chewing.[1] Teeth have an important role in mastication and phonetics. Disruption of one of the components of the stomatognathic system, such as loss of all teeth, can result in an imbalance in its function. Decreasing masticatory, phonetic, and aesthetic functions result in diminishing general health and quality of life of the patient.[2]

Edentulism or full edentulous, is the loss of all natural teeth in the oral cavity. Edentulism results in reduced height of the lower third of the face, vertical dimension, disorders of mastication, social and psychosocial problems, aesthetics, and phonetics that affect on a person's quality of life.[3-6] Oral rehabilitation using complete dentures is required to improve mastication in fully edentulous patients. Complete dentures help restoring mastication, phonetic, and aesthetic hence a person can return to normal interactions. Mastication is the first step in the digestive process, when food is reducing into smaller particle and lubricated with saliva then formed into a cohesive mass called as a food bolus.[7]

In patients who wear ill-fitting dentures, it can result in changes to the alveolar ridge changes shape significantly in both the horizontal and vertical axes following a predictable pattern. As resorption continues from the labial and lingual aspects, the crest of the ridge becomes increasingly narrow ultimately becoming knife-edge. As the process continues, the knife-edge becomes shorter and even eventually disappears, leaving a low well rounded or flat ridge. Eventually, this too resorbs, leaving a depressed ridge.[8]

The priority of prosthetic rehabilitation in edentulous patients is to restore the function of the stomatognathic system with optimal retention and stability of the complete denture.[9] The success of complete denture depends on the condition of the alveolar ridge. The magnitude and direction of masticatory load applied to the denture will be distributed on the oral mucosa under the denture base. An effort to manage Knife-ridge is to modify the impression technique that can minimize pressure on the alveolar mucosa and modify by the type of occlusal schemes, such as using a lingualize occlusion to decreasing lateral force, There is some evidence that Lingualize Occlusion is beneficial for patients with severely resorbed ridges in terms of mastication and stability.[9,10]

The influence in the bone structure of the residual ridge can be a cause of chronic pain under the denture, especially when performing masticatory movements. When the knife-edge ridge is

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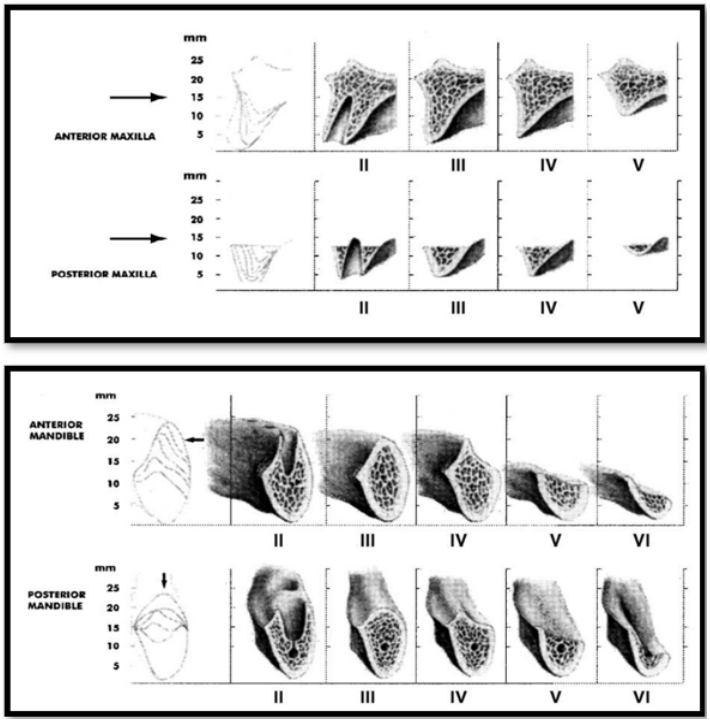

Figure 1. Cawood and Hawell classify the residual ridge

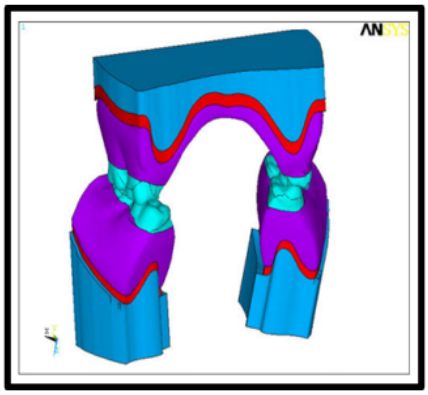

Figure 2. FEM model of maxillary and mandibular complete denture in first molar region showing the underlying mucosa and alveolar bone

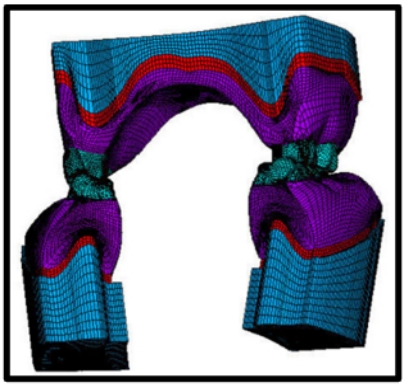

Figure 3. F3D FEM model of maxillary mandibular complete denture with mesh

given a load, the existing mucosa will be wedged between the base of the denture and bone, which will then cause pain.[11]

Masticatory function in complete denture wearers can be objectively assess by measuring masticatory performance. Masticatory performance is a measurement of food particle distribution under standard test conditions and demonstrates the comprehensive capabilities required for mastication. Masticatory performance can be measured with conventional methods such as sieving and mixing ability methods. Conventional methods of measuring masticatory performance require a large number of samples in the study. Digitally, finite element method (FEM) can be used to measure masticatory performance of complete denture wearers using only one sample related to stress distribution and displacement of the alveolar ridge against masticatory load.[12]

Base on the research use a finite element to build a model of the mandible, including the TMJ from the commercial software Abaqus FEM, to simulate the process of mastication cycle.[13]

This paper aims to discuss the use of FEM in the measurement of stress distribution on the Knife-Ridge of complete dentures with various occlusal schemes.

Literature Studies

Knife Edge Ridge

The Knife-edge ridge is included in one of the compromised ridges due to the process of resorption ridge. A knife-edge ridge is a ridge with sharp bones and is a problem that often occurs in edentulous patients. The knife-edge ridge formed because of the rapid resorption of the labial and lingual sides of the anterior lower jaw.[14]

Teeth may be lost due to several reasons tooth decay, periodontal problems, and tooth injury being the most frequent causes of tooth loss. When tooth loss occurs the alveolar ridge undergoes a series of changes that lead to different shapes of ridges, thus forming residual ridges.[15,16]

The size of residual ridge is reduced most rapidly in the first six months, but resorption of bone continues throughout the life at a slower pace that leads to changes in bone form and structure.[17,18] Maxilla resorbs superiorly and posteriorly; however, mandibular resorbs in inferior and anterior directions. The anterior mandibular resorbs four times faster than the anterior maxilla. Cawood and Hawell classify the residual ridge to basic six classes: Class I - dentate; Class II -immediately post extraction; Class III- well-rounded ridge form, adequate in height and width; Class IV - knife-edge ridge form, adequate in height and inadequate in width; Class V flat ridge form, inadequate in height and width; Class VI - depressed ridge form, with some basilar loss evident.

Moreover they found that the Pattern of bone loss varies with sites. Anterior mandibular bone loss is vertical and horizontal (from the labial aspect). Posterior mandibular bone loss is mainly vertical. Anterior maxilla - bone loss is both vertical and horizontal (from the labial aspect). Posterior maxilla - bone loss is both vertical and horizontal (from the buccal aspect).[20]

Masticatory Performanc[22] Masticatory performance is an achievable measure of food distribution under standard test

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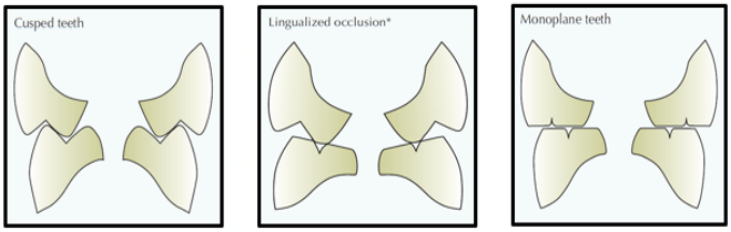

Figure 3. Tooth Molds and Occlusal Concepts

conditions and demonstrates the comprehensive capabilities required for mastication. Conventional masticatory performance measurement can be done by two methods:

Comminution method

These method use food that has been crushed into smaller particles. Smaller particle size indicates better mastication performance. Can be divided into four methods: A sieving method that assesses the fragmentation and particle size distribution by single or multiple sieves or through several types of optical scanning and digital image analysis; Gummy jelly (GJ) method which involves measuring the extraction of glucose released from gummy jelly after chewing; the amount of glucose released is related to the degree to which the test food is fragmented; The fuchsin bead method which uses encapsulated fuchsin beads as food to assess masticatory performance. The fuchsin dye was released into the capsule when the beads were chewed, and the concentration of the dye released, which was proportional to the masticatory performance and was measured by a spectrophotometer; Colorimetric methods that assess food fragmentation tests by the release or binding of dyes from solution. The dye concentration is assessed by a spectrophotometer, which is proportional to the masticatory performance.

Mixing ability

To assess masticatory performance, the mixing ability method used two-colored gum or wax and color-changing gum. The color change that occurs in the gum or wax determines the value of masticatory performance.[22]

Finite Element Method (FEM)

FEM is a numerical method to get a solution to a problem accurately with modeling simulations to be analyzed mathematically. The continuous structure is divided into different elements, retaining the properties of the original structure under study. Each element is described by a different equation and solved by a mathematical model.[23]

FEM can analyze stress and strain as a result of external pressure, temperature changes and other factors. It is therefore not possible to measure stress and strain in human tissues in response to external stresses. This method is very useful for examining the mechanical aspects of biomaterials in human tissue. The results can be examined with software related to the FEM to look at the various parameters and identify the analysis of their implications.[23]

The advantages of FEM are: Minimize animal research; Non-invasive; Can visualize superimposed structures; Easier analysis of material properties of craniofacial structures and geometries; The direction and magnitude of the pressure can be located precisely; Theoretical measurement of the load point; Static and dynamic analysis can be performed; Research can be done repeatedly.; Time efficiency

The limitations of the FEM, are: Researchers need to understand material properties well; Errors in inputting data can result in errors in output; Requires a lot of input data.

Occlusal Schemes

Reduced the mucosal area of denture support on the knife ridge, requires treatment by minimizing the load that the cusp will receive and reducing resistance during movement to prevent pain.[24] One of the efforts can be made is to arrange the occlusion schemes other than bilateral balanced occlusion schemes, for example lingualized or monoplane occlusion.[25,26]

The bilateral balanced occlusion scheme uses anatomical factors to give a more natural appearance and good masticatory efficiency. The lingualized occlusion scheme uses anatomical factors in the maxilla and non-anatomical factors in the mandibular to make the premolar area still looks natural. The monoplane occlusion scheme uses non-anatomical factors throughout so that lateral movement reduces stress on the mucosa.[25]

This difference in the shape of the artificial teeth helps in reducing the load that will be transmitted to the periphery and also minimizes resistance during movement, but the impact is reduced masticatory efficiency, less aesthetic appearance, and modifications to the annulus that need to be made.[25-27] This becomes even more apparent when the occlusion scheme chosen is a monoplane with an entirely non-anatomical.

Discussion

The resorption that occurs on the margins of the edentulus is a consequence of tooth extraction and long-term denture use.[29,30] A systematic review conducted by Pham et al on several studies measuring the resorption rate on the posterior mandibular of patients with complete denture users, found that the average resorption on the posterior mandibular ranged from 0.01-2.4 mm per year. This figure has a very large variation and is different from that proposed by Laing and Zarb who stated that this resorption ranges from 0.1-0.2 mm per year. This difference is thought to be due to the occlusion scheme used, of which there were only seven studies that used bilateral balanced.

A study conducted by Alsaggaf and Fenlon[31] even found that patients who used a denture for more than 5 years experienced significant residual resorption when compared to the group who did not use a denture. This contradicts Wolf's Law, which states that the edentulus will atrophy if not used a denture.[32] The author believes that other factors play a role so that resorption in denture users is more significant, one of which is the possibility that the load distributed by the denture is uneven that it exceeds the tolerance threshold of the underlying mucosa.

The concept of occlusion is still an interesting discussion regarding prosthodontic efforts to produce a stable denture. Bhambhani et al[33] in their systematic review stated that in the BBO occlusion scheme, the deflective contact of the anatomical form of the annulus can cause the denture to become unstable. Similarly, in a randomised clinical trial study patients with BBO occlusion scheme dentures tend to avoid some foods that cause discomfort due to frequent denture instability, although in the assessment of masticatory efficiency no difference was found compared to other occlusion schemes.[34]

Studies related to the comparison of various occlusion schemes in denture users are based on mastication efficiency or mastication performance, which is subjectively assessed by patients when using a denture and without using standardised test foods. In

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addition, the inability of patients to crush food due to low resilience can be expected due to the load received exceeding the mucosal tolerance threshold, which cannot be detected by mastication performance assessment.[35]

Other in vitro studies were conducted directly on the denture, but modelling of the edentulus plate could not represent the complex native conditions, making it inadequate to study the stress distribution in oral structures.[36]

Assessed the stress distribution by FEM on the mucosa under the denture base with 33^0, 20^0, and 0^0 cuspal teeth. Cross-sections of the denture were graphed and normal bone contours were obtained from CT results, with a load of 50 N. The stress values revealed that greater stress values were observed in the 20^0 and 33^0 cuspal teeth than in 0^0 teeth. The shortcoming of this study is the use of two-dimensional FEM testing so that the resulting stress distribution is only assessed at a certain point that does not necessarily receive the largest load when functioning.[37]

How the shape of the posterior cuspal teeth with inclinations of 0^0, 20^0, and 33^0 resulted in different stress distributions under the tissues of a complete denture when it received a masticatory load of 100N in the vertical direction. The results showed that inclinations of 20^0 and 33^0 produced greater stress distribution values than 0^0, while between 20^0 and 33^0 showed no significant difference. This was expected because different inclinations would cause a change in the load direction and the greater the inclination, the less the contact area with the antagonist. However, this study did not include the variable oblique load direction to represent lateral movement, which is most prone to cause interference with denture retention and stabilisation.[37] The research about knife edges is limited to impression techniques, while the selection of occlusion schemes has not been carried out on knife edges.

Conclusion and Suggestion

The treatment of edentulus cases, especially on knife ridge, requires a deeper understanding of how the occlusion scheme can play a role in maximizing the patient's masticatory performance while maintaining the condition of the mucosa and the underlying alveolar bone from pain and further resorption. The utilization of FEM with simulated modeling obtained is similar to the original condition, so it can help describe how the stress distribution received by the mucosa under the denture base and conduct further analysis related to pain and possible resorption risks that can occur.

Several studies related to the utilization of FEM in assessing the stress distribution on the mucosa under the denture have focused on normal residual ridge conditions and bilateral balanced occlusion schemes, more studies need to be conducted related to crowding conditions with various occlusion concepts, so that it can be applied theoretically and clinically.

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