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PAIN AND STRESS DISTRIBUTION IN KNIFE EDGE RIDGE BENEATH COMPLETE DENTURE AND SOFT DENTURE LINER WITH DIFFERENT THICKNESSES USING FEA

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Abstract

Complete denture wearers with knife edge ridge often experience pain and discomfort. This condition is a result of the pressure beneath the complete denture over the physiological and mechanical capacity of the alveolar ridge. Soft denture reline (SDL) is one of the treatments to relieve pain, thereby improving the patient's comfort due to cushioning effect and reducing the stress on supporting tissue by distributing occlusal load in the alveolar ridge. The thickness of the reline material influences the stress distribution. Finite Element Analysis (FEA) allows simulation of the complex biomechanical conditions of the denture over the thin mucosa, thereby allowing the assessment of stress distribution in the superficial mucosa and alveolar ridge. This literature review aims to analyze the stress distribution in the knife edge ridge beneath the complete denture with autopolymerized SDL acrylic-based and SDL silicon-based with different thicknesses. Autopolymerized soft denture liners are widely chosen because they can be applied in a chairside one visit. Based on research using FEA, an SDL thickness of 2 mm can decrease the stress in the mucosa and the underlying bone. In contrast, according to Parr and Rueggberg, the ideal thickness of SDL is 2-3 mm. Lima et al stated that an SDL thickness of 2.5 mm showed a slightly higher level of stress. Silicone liner showed a lower amount of stress on the mucosa and alveolar ridge than the acrylic liner, despite the use of 2 mm SDL being the ideal thickness for distributing stress optimally and relieving pain.

Keywords: Complete Denture; Soft Denture Liner; Stress Distribution; Pain Analysis; Finite Element Analysis.

INTRODUCTION

Complete loss of teeth, known as edentulism, is a condition that can impair mastication, phonetics, and aesthetics. This condition has a high prevalence globally and affects around 0.1-14.5% of people under the age of 50 years and 2.1-32.3% of the elderly worldwide. In Indonesia, the prevalence of edentulousness, according to Pengpid and Pletzer, is higher than in Ghana, Laos, Myanmar, and Vietnam but lower than in India, Malaysia, Mexico, the Philippines, and Russia.[1] The World Health Organization (WHO) considers edentulousness a physical disorder, disability, and handicap in patients because of the patient's inability to speak and masticate properly.[2]

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Edentulism can also cause alveolar bone resorption, and it is a chronic, multifactorial, and progressive condition that develops gradually proceeds throughout an edentulous patient's lifetime.[3–6]

The mandible tends to undergo greater alveolar bone resorption compared to the maxilla,[6,7] this leads to a decrease in the height and area of the supporting tissue beneath the complete denture.

As a result, failure in using complete dentures due to prostheses instability and lack of retention causes the masticatory load over the mechanical and physiological capacity of the alveolar bone.[8]

This situation often occurs on the knife edge ridge. [4,6] Furthermore, instability and lack of retention of complete dentures cause an imbalance in masticatory force and do not have uniform stress distribution, leading to injury and trauma of the mucose membrane under the denture, which, over time, causes physiological changes to become thin and atrophic.[9]

The mucous membrane and the alveolar ridge are the foundation of the denture.[7] Injuries to the mucous membrane stimulate pain and cause discomfort in the complete denture wearer, reducing masticatory performance and masticatory efficiency in patients and lowering the pressure pain threshold. It causes 80% of failures in using dentures [7,8,10] which affect the quality of life[11].

One of the treatment solutions to the problem of discomfort while wearing dentures is to use a soft denture liner. Soft denture liners consist of acrylic-based and silicon. These liners have the mechanical properties of being flexible, resilient, and shock-absorbed.[3] The properties of soft denture liners can absorb the stress of occlusal force during mastication and distribute it uniformly.

Thereby, less force is transmitted to the alveolar bone, reducing pain during mastication and maximizing the use of dentures. Another impact of using a soft denture liner is that it can minimize the alveolar bone resorption that occurs [5,9,12–14], which at a certain thickness can maximize the benefit of these liners and compensate for loss of thickness in the mucosa. [4,15–17]

Various methods can be used to analyze the stress distribution and pain, using photoelasticity, strain measurements, brittle lacquer, and Finite Element Analysis (FEA).[18] FEA is widely used in silico[19] to estimate the load on the mucosa under dentures [18] because FEA can produce biomechanical information on the characteristics of dentures and supporting tissues quantitatively and qualitatively.[18,20] Furthermore, this method can be used to compare the physical properties of various supporting structures.[15]

This literature review aims to assess the distribution of pressure and pain from the denture to the knife edge using autopolymerization of acrylic soft denture liner and silicon soft denture liner using finite element analysis.

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LITERATURE STUDY

Complete Denture

Acrylic complete dentures as mucous membrane-supported dentures, function on the mucous membrane that covers the edentulous process of the denture foundation. This type of prosthesis is the most commonly used treatment for restoring dentition.[21] However, the use of removable complete dentures may have a high incidence of failure and discomfort due to inadequate retention and stabilization, which can cause pain. One of the leading causes of this problem is the gradual loss of alveolar bone, which can result in denture instability. This resorption is more pronounced in the mandible, occurring four times faster than in the maxilla. When the resorption occurs more in the labio-lingual and from the vertical direction, it can cause the ridge to become thin and sharp, known as a knife edge.[6,22,23]

The foundation of dentures that rests on the knife-edge mandibular ridge provides minimal resistance to the movement of the denture base. During mastication, this area undergoes substantial displacement, resulting in an unstable and imbalanced masticatory movement.[2425] this can lead to localized high stress on the mucosa [26]cause the thin mucosa under the denture is susceptible to ulceration due to friction between the loose denture base, resulting in pain and limited use of the denture.[27]

Mucosal Biomechanical Response to Pain and Stress

Localized excessive stress under a complete denture can cause pain in the mucosa. Typically, the mucosa is resistant to deformation from masticatory load.[10] It distributes the forces of mastication to protect the underlying residual with a cushioning effect. However, the denture wearer reduces keratinization of the epithelium, resulting in a mechanically weak mucosal surface that produces less protection mechano-receptor; therefore, constant pressure from the denture causes local ischemia and pressure ulcers, leading to reduced PPT.[28]

The Minimum pressure that induces pain is known as PPT. PPT of the mucosal membrane is the most important property of the denture foundation in determining the lowest pressure that can trigger pain.[7,10] It is worth noting that long-term denture wearing can decrease PPT by up to 40%.[28] This indicated that denture wearing makes the mucosa more pain-sensitive to pressure. The average PPT in the edentate state area is 630 KPa[19,25]; however, this PPT depends on age, mucosa elasticity, the alveolar ridge thickness, the innervation pattern, and receptor density. [7,25,29]

The thickness of the mucosa in the maxilla is greater than the mandible, resulting in lower PPT on the ridge crest of the mandible. This is due to the greater mucosa elasticity in the maxilla. PPT increases from the anterior alveolus to the posterior alveolus in both the maxilla and mandible, decreasing from the ridge crest to the buccal vestibule. Studies suggest that sensory receptors are commonly located in the anterior part of the ridge, and the receptor density is reduced in the ridge crest compared to the vestibule, although the details are unknown. [25,29]

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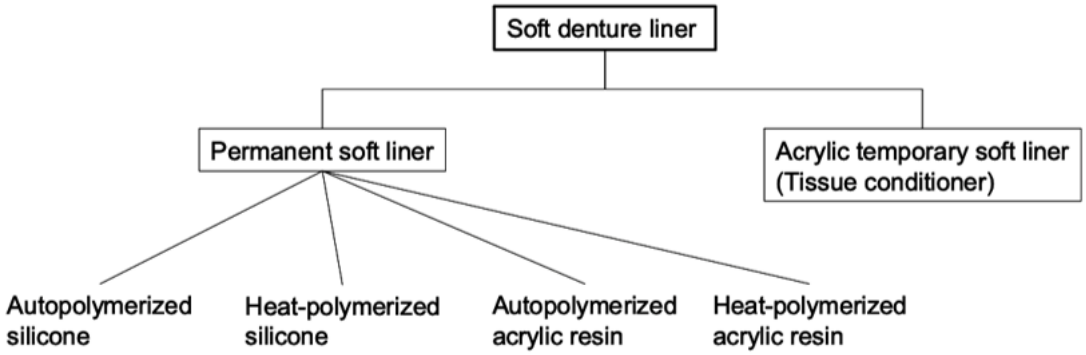
Studies indicate that the pressure pain threshold (PPT) in the knife-edge ridge mandible is notably lower when compared to the flat alveolar ridge. [25,29] However, there exists a viable solution to this issue. The utilization of a soft denture liner has been demonstrated to significantly alleviate discomfort and increase the pain threshold, thus promoting enhanced comfort and an improved quality of life for a denture wearer.

Soft Denture Liner

Soft denture liners are more indicated to relieve pain resulting from wearing dentures on alveolar ridges with undercuts or residual ridges with poor anatomy such as knife-edge ridges.[30,31]The International Organization for Standardization (ISO) categorized soft denture liners as short-term and long-term, a long-term soft denture liner will maintain its resilient properties for more than 30 days and can be used for up to 1 year, while a short-term soft denture liner recommended use for up to 30 days. Murata then classified soft denture liners based on SDL viscoelasticity properties into permanent soft liners and acrylic temporary soft liners. Permanent soft liners are then classified into (1) auto polymerized silicone, (2) heat-polymerized silicone, (3) auto polymerized acrylic resin, and (4) heat-polymerized acrylic resin. SDL acrylic temporary is classified as a tissue conditioner.[31]



The use of SDL can provide numerous benefits for denture wearers, including improved masticatory function with a cushion effect. By distributing the masticatory force and absorbing the occlusal force from the denture to the underlying supporting tissue, the liner can reduce stress and pain, and minimize the alveolar ridge's resorption. Furthermore, uniform distributing of the functional load helps the inflamed mucosa heal in the support area of the prostheses and improves their adaptation and retention.[31,32] However, to achieve optimal cushioning, it's essential that the Elastic Modulus (ME) of the SDL matches that of the mucosa.[13] This is because the SDL compensates for the loss of thickness in the mucosa. If the ME of the liner is lower than that of the mucosa, stress distribution may be inadequate and can be distributed adversely. Therefore, it's important to ensure that the ME of the SDL is the same as that of the mucosa in order to maximize

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its benefits. Experts recommend that the thickness of the SDL be between 2-3 mm to ensure uniform stress distribution and prevent any weakening of the denture base.[33]

Permanent SDL consists of autopolymerization and hot polymerization. The use of auto-polymerized SDL is often preferred because it is fast and easy. This option does not require a laboratory process, allowing patients to use their newly relined dentures immediately.[34]

The SDL's viscoelastic properties can determine the material's elasticity, represented by the storage modulus (E'). Meanwhile, the material's viscosity is represented by the loss modulus (E"), and the ratio of E' to E" is represented by the loss tangent (δ), which indicates the cushioning effect against masticatory force. Compared to tissue conditioners, acrylic permanent soft liners, and silicone permanent soft liners exhibit an increase in the storage modulus (E') value. Acrylic permanent soft liners have the highest loss modulus (E") value, with a δ higher value than silicone permanent soft liners. This suggests that permanent acrylic material has viscoelastic properties, while permanent silicone material has elastic properties. [31,35]

Acrylic soft Liner material would have a greater ability to cushion the masticatory force and improve masticatory function than Silicon soft Liner. However, Acrylic Permanent Soft Liner depends on frequency and time because it contains Plasticizer material. When immersed using a denture cleaner, this plasticizer material leaches out into the water, and at the same time, water is absorbed into the material and leads to dimensional changes and deterioration to the surface of the material. The silicon material remains stable over time, and this would be due to low water absorption and low solubility component.[31,35,36 35] The smooth surface *silicone-based resilient liner* can inhibit bacterial growth and ensure the cleanliness of dentures for a long time.[37]

Finite Element Analysis

The Finite Element Analysis (FEA), or The Finite Element Method (FEM), is a computer-based method that involves dividing the structure into small elements and connecting them at nodes to analyze its structural behavior. In the field of prosthodontics, Finite Element Analysis (FEA) is a non-invasive technology that produces qualitative and quantitative information from the biomechanical characteristics of dental prostheses and their supporting structures which can analyze the masticatory load under the denture base. This method has proven to be an effective tool for accurately evaluating the structural integrity of denture bases, analyzing the structure of a denture base, and determining the optimal thickness of soft liner material therefore the pressure patterns and stress distribution between the denture and the mucosa can be predicted with little chance of failure. [7,38,39]

In order to perform FEA analysis, it is crucial to create an accurate finite element (FE) model. This involves capturing specific material properties, loads, and unique conditions for precise simulation. FEA can provide detailed quantitative data at any location within a mathematical model, so it is a valuable analytical tool in dentistry.[20]

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DISCUSSION

One of the consequences of tooth loss is resorption of the alveolar ridge. According to the literature, the greatest resorption of the alveolar ridge occurs in the first month after tooth extraction and decreases over time. The greatest resorption occurs in the mandible compared to the maxilla in the early stages of edentulism and reduces over time, causing changes in the width and height of the alveolar bone and thinning of the mucosa in the mandible, which is the support area for the denture.[5,43]50%-84% of this situation will cause the failure of the use of dentures and cause further resorption because of the stress beneath the denture, resulting in a painful stimulus that causes a reduction of 40% of pain pressure threshold (PPT) and lead to limitations in mastication.[6,14,44]

Denture relining is a treatment that is widely used to restore comfort and increase success in using complete dentures. The resilient denture liners or Soft denture liners (SDL) are frequently recommended in extremely absorbed residual ridge cases, irregular bone resorption such as knife edge ridge , and atrophic mucosa, among others, because they act as a cushion effect resulting in a homogeneous functional load distribution to the denture supporting the tissue. This viscoelastic nature of SDL can also reduce 50% of the resorption rate that occurs within 12 months of use compared to not using SDL, according to Babu et al. [5] this is due to the uniform stress distribution under the denture and the small amount of force transmitted to the alveolar bone. However, the denture relines' stress distribution and cushion function may be affected by their physical properties, composition, and thickness.

A comparison of acrylic and silicon soft liners discovered that acrylic liners offer greater cushioning, while silicon liners exhibit superior resistance and resilience.[11,45–47] Additionally, a study conducted by Kimoto et al. [48] showed that acrylic resilient dentures offer greater durability, allowing for longer periods of use. On the other hand, according to Shrivastava et al. [20], silicone soft denture liners do not uniformly distribute stress during loading, whereas acrylic soft denture liners effectively absorb stress due to their cushioning effect.[11] Contrary to Kimoto, Alqutaibi et al. [11] stated that A 3-month follow-up study revealed that silicone-based liners performed better than acrylic-based liners in terms of both Masticatory Bite Function and Masticatory Efficiency. This could be attributed to the chemical properties of the acrylic-based liners. The plasticizers used in this type of soft liners are not bound to the resin and would thus leach out with time with a consequent decline in the initial favorable viscoelasticproperties[49]

Kimoto et al.[45] also demonstrated that silicone-based liners were found to enhance masticatory performance as measured by the sieving method, which involved 3 g peanuts and 20 chewing cycles on the preferred side. Moreover, a study conducted by Furokawa et al.,[44] demonstrated that wearing mandibular complete dentures with silicone-based resilient denture liners increased the pain threshold in edentulous patients.[45]

The thickness of the soft liner plays a role in getting maximum cushioning effect on the SDL, which plays a role in distributing stress on the mucosa, especially on thin mucosa.

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Parr and Rueggberg stated that the liner material should have a minimum 2-3 mm thickness. However, a contradicting result report by Santos et al. stated that 3 mm is the minimum SDL thickness that produces satisfactory results. In their FEA research, Lima et al., [15] said that the ideal thickness of 2 mm of soft liner produces a lower pressure distribution than not using a soft liner or a soft liner with another thickness, namely 0.5, 1, 1.5, 2.5. Moreover, there was a slight increase in pressure on the mucosa and underlying bone at a thickness of 2.5 mm SDL. [15] These results also align with research by Ahmed Husein et al.[4], who stated that a soft liner thickness of 2 mm can reduce stress on the mucosa and supporting tissue under the denture.

CONCLUSION

Denture lining can prevent friction between the base and the mucosa, thereby eliminating pain, minimizing resorption of the alveolar ridge, and increasing retention and stabilization of the denture by stress distribution in the alveolar ridge mucosa. In addition, silicone liners are more widely used than acrylic soft liners because they are more durable and can maximize chewing performance and function, where a soft denture layer of 2 mm thick is considered the ideal thickness with minimal pressure on the mucosa and alveolar bone.

SUGGESTION

In order to confirm the above-mentioned findings, clinical comparison and evaluation of stresses developed in denture-supporting tissues following the use of acrylic and silicon soft liners should carried out. In addition, the clinical effects of using different thicknesses of each soft liner in denture-supporting tissues should be evaluated.

Reference

1) Pengpid S, Peltzer K. The prevalence of edentulism and their related factors in Indonesia, 2014/15. BMC Oral Health. 2018 Jul 3; 18(1).

2) Lee DJ, Saponaro PC. Management of Edentulous Patients. Vol. 63, Dental Clinics of North America. W.B. Saunders; 2019. p. 249–61.

3) Kimoto S, Kimoto K, Murakami H, Gunji A, Ito N, Kawai Y. Survival analysis of mandibular complete dentures with acrylic-based resilient liners. Gerodontology. 2013 Sep; 30(3):187–93.

4) Ahmed Hussein L. 3D finite element analysis of the influence of different soft lining materials with variable thicknesses on stress transmitted to underlying mucosa [Internet]. Vol. 2, International Journal of Advanced Research. 2014. Available from: http://www.journalijar.com

5) Dinesh Babu B, Jain V, Pruthi G, Mangtani N, Pillai RS. Effect of denture soft liner on mandibular ridge resorption in complete denture wearers after 6 and 12 months of denture insertion: A prospective randomized clinical study. Journal of Indian Prosthodontist Society. 2017 Jul 1; 17(3):233–8.

6) Marcello-Machado RM, Bielemann AM, Nascimento GG, Pinto L de R, Del Bel Cury AA, Faot F. Masticatory function parameters in patients with varying degree of mandibular bone resorption. J Prosthodont Res. 2017 Jul 1; 61(3):315–23.

ISSN: 1673-064X
E-Publication: Online Open Access
Vol: 67 Issue 03 | 2024
DOI: 10.5281/zenodo.10848566

7) Żmudzki J, Chladek G, Kasperski J. Biomechanical factors related to occlusal load transfer in removable complete dentures. Biomech Model Mechanobiol. 2015 Aug 29; 14(4):679–91.

8) Zmudzki J, Chladek G, Żmudzki J, Chladek G, Malara P, Dobrzański LA, et al. The simulation of mastication efficiency of the mucous-borne complete dentures “Applied Simulation and Experiment Research in Dentistry” A special issue of Applied Sciences IF 2,217 View project Complete denture biomechanics View project The simulation of mastication efficiency of the mucous-borne complete dentures [Internet]. 2013. Available from: https://www.researchgate.net/publication/285929841

9) Yankova M, Peev T, Yordanov B, Dimova-Gabrovska M, Todorov R. Application Of Resilient Denture Lining Materials: Literature Review. Journal of IMAB - Annual Proceeding (Scientific Papers) [Internet]. 2021 Apr 2; 27(2):3676–81. Available from: https://www.journal-imab-bg.org/issues-2021/issue2/vol27issue2p3676-3681.html

10) Chen J, Ahmad R, Li W, Swain M, Li Q. Biomechanics of oral mucosa. Vol. 12, Journal of the Royal Society Interface. Royal Society of London; 2015.

11) Alqutaibi AY, Alnazzawi AA, Farghal AE, Bakr RM, Mahmoud II. Impact of Acrylic and Silicone-Based Soft-Liner Materials on Biting Force and Quality of Life of the Complete Denture Wearers: A Randomized Clinical Trial. J Clin Med. 2023 Mar 1; 12(5).

12) Kimoto S, Kimoto K, Gunji A, Kawai Y, Murakami H, Tanaka K, et al. Clinical effects of acrylic resilient denture liners applied to mandibular complete dentures on the alveolar ridge. J Oral Rehabil. 2007 Nov; 34(11):862–9.

13) Sadr K, Alipour J, Heidary F. Finite Element Analysis of Soft-lined Mandibular Complete Denture and its Supporting Structures. J Dent Res Dent Clin Dent Prospects [Internet]. 2012; 6(2):37–41. Available from: http://www.ncbi.nlm.nih.gov/pubmed/22991634

14) Kar S, Tripathi A, Fatima T. A comparative study of masticatory performance in complete denture patients before and after application of soft liner. Med J Armed Forces India. 2019 Oct 1; 75(4):437–43.

15) Lima JBG, Orsi IA, Borie E, Lima JHF, Noritomi PY. Analysis of stress on mucosa and basal bone underlying complete dentures with different reliner material thicknesses: A three-dimensional finite element study. J Oral Rehabil. 2013 Oct; 40(10):767–73.

16) Radi IAE, Elmahrouky N. Effect of two different soft liners and thicknesses mediating stress transfer for immediately loaded 2-implant supported mandibular overdentures: A finite element analysis study. Journal of Prosthetic Dentistry. 2016 Sep 1; 116(3):356–61.

17) Fatihallah AA. Effect of soft liner-denture base thickness on load transmitted to the underlying mucosa. A three dimensional finite element analysis. Vol. 21, J Bagh College Dentistry. 2009.

18) Mousa M, Jamayet N, Lynch E, Husein A. Biomechanical stress in removable complete dental prostheses: A narrative review of finite element studies. Vol. 12, Journal of International Oral Health. Wolters Kluwer Medknow Publications; 2020. p. 413–9.

19) Paras A, Ma S, Waddell JN, Choi JJE. Denture–Mucosa Pressure Distribution and Pressure–Pain Threshold in In Vivo, In Vitro and In Silico Studies: A Literature Review. Oral. 2022 Mar 7; 2(1):112–25.

20) Shrivastava R, Chaturvedi S, Verma AK, Ali M, Nagendra A, Chaturvedi M. Stress distribution under commercial denture liners- a finite element and clinical analysis. Journal of Clinical and Diagnostic Research. 2016 Dec 1; 10(12):ZC14–8.

21) Zmudzki J, Chladek G, Kasperski J. The influence of a complete lower denture destabilization on the pressure of the mucous membrane foundation. Acta Bioeng Biomech. 2012; 14(3):67–73.

ISSN: 1673-064X
E-Publication: Online Open Access
Vol: 67 Issue 03 | 2024
DOI: 10.5281/zenodo.10848566

22) Nishimura I, Atwood DA. Knife-edge residual ridges: A clinical report. 1994.

23) Samyukta, DrAbirami G. Residual Ridge Resorption in Complete Denture Wearers. 2016.

24) Pero AC, Scavassin PM, Policastro VB, de Oliveira Júnior NM, Mendoza Marin DO, Silva MDD da, et al. Masticatory function in complete denture wearers varying degree of mandibular bone resorption and occlusion concept: canine-guided occlusion versus bilateral balanced occlusion in a cross-over trial. J Prosthodont Res [Internet]. 2019; 63(4):421–7. Available from: https://doi.org/10.1016/j.jpor.2019.03.005

25) Żmudzki J, Chladek G, Malara P. Use of finite element analysis for the assessment of biomechanical factors related to pain sensation beneath complete dentures during mastication. Journal of Prosthetic Dentistry. 2018 Dec 1; 120(6):934–41.

26) LU Ya lin LH di, RQ guo,DONG JXJ. Stress area of the mandibular alveolar mucosa under complete denture with linear occlusion at lateral. Chin Med J (Engl). 2010; 917–21.

27) Policastro VB, Cassiano AFB, da Silva MDD, Viotto HEDC, Leite ARP, Marin DOM, et al. Influence of the height of the mandibular ridge on the masticatory function during the functional adaptation with new complete dentures. Journal of Applied Oral Science. 2020; 28:1–11.

28) M. TANAKA TOKKTO. Denture wearing and strong bite force reduce pressure pain threshold of edentulous oral mucosa. 2004.

29) Ogawa T, Tanaka M, Ogimoto T, Okushi N, Koyano K, Takeuchi K. Mapping, profiling and clustering of pressure pain threshold (PPT) in edentulous oral mucosa. J Dent. 2004 Mar; 32(3):219–28.

30) Kreve S, Dos Reis AC. Denture Liners: A Systematic Review Relative to Adhesion and Mechanical Properties. Vol. 2019, Scientific World Journal. Hindawi Limited; 2019.

31) Murata H. Rheology - Theory and Application to Biomaterials. In: Polymerization. InTech; 2012.

32) Kouser M, Nair C, Khurana A, Saifi D, Budakoti V, Shukla AK. Effect of Different Denture Soft Liners on Mandibular Ridge Resorption in Complete Denture Wearers: An In-vivo Study [Internet]. Vol. 38, International Journal of Scientific Study. 2021. Available from: www.ijss-sn.com

33) Sato Y, Abe Y, Okane H, Tsuga & K. Finite element analysis of stress relaxation in soft denture liner. Journal of Oral Rehabilitation. 2000.

34) Puangpetch M, Wiwatwarrapan C. Effect of Methyl Formate-Methyl Acetate Treatment on Flexural Strength of Relined Denture Base. 2019; 69.

35) Murata H, Hamada T, Sadamori S. Relationship between viscoelastic properties of soft denture liners and clinical efficacy. Vol. 44, Japanese Dental Science Review. 2008. p. 128–32.

36) MH Abdelnabi AAS. Silicone versus acrylic resilient long term soft liners; a cross-over clinical study. Curr Sci Int. 2020; 09(01):1–11.

37) Ibraheem EMA, Hammad HGH. Impact of long-term soft relining of mandibular complete dentures on brain activity and cognitive function of elderly patients. Open Access Maced J Med Sci. 2020 Oct 15; 8(D):158–65.

38) Meira JBC, Jikihara AN, Capetillo P, Roscoe MG, Cattaneo PM, Ballester RY. Finite Element Analysis in Dentistry. In 2018. p. 67–89.

39) Chopade S, Madhav V, Palaskar J. Finite element analysis: New dimension in prosthodontic research. Journal of Dental and Allied Sciences. 2014; 3(2):85.

ISSN: 1673-064X
E-Publication: Online Open Access
Vol: 67 Issue 03 | 2024
DOI: 10.5281/zenodo.10848566

40) Mousa M, Jamayet N, Lynch E, Husein A. Biomechanical stress in removable complete dental prostheses: A narrative review of finite element studies. Vol. 12, Journal of International Oral Health. Wolters Kluwer Medknow Publications; 2020. p. 413–9.

41) Żmudzki J, Chladek G, Malara P. Use of finite element analysis for the assessment of biomechanical factors related to pain sensation beneath complete dentures during mastication. Journal of Prosthetic Dentistry. 2018 Dec 1; 120(6):934–41.

42) Bandela V, Kanaparthi S. Finite Element Analysis and Its Applications in Dentistry [Internet]. Available from: www.intechopen.com

43) Jadhav MS, Rathod P, Hasban S, Swati P. Residual Ridge Resorption A Challenge To Conquer: A Review. IOSR Journal of Dental and Medical Sciences (IOSR-JDMS) e-ISSN [Internet]. 2021; 20:49–57. Available from: www.iosrjournals.org

44) Furokawa S, Kimoto S, Furuse N, Furuya Y, Ogawa T, Nakashima Y, et al. The effects of silicone-based resilient denture liners on pain: A randomized controlled trial. J Prosthodont Res. 2020 Oct 1; 64(4):417–23.

45) Furuya Y, Kimoto S, Furuse N, Igarashi K, Furokawa S, Kawai Y. Effectiveness of silicone-based resilient denture liners on masticatory function: A randomised controlled trial. J Dent. 2021 Jun 1; 109.

46) Nowakowska-Toporowska A, Malecka K, Raszewski Z, Wieckiewicz W. Changes in hardness of addition-polymerizing silicone-resilient denture liners after storage in artificial saliva. Journal of Prosthetic Dentistry. 2019 Feb 1; 121(2):317–21.

47) Silicone versus acrylic resilient long term soft liners; a cross-over clinical study. Curr Sci Int. 2020;

48) Kimoto S, Kimoto K, Gunji A, Kawai Y, Murakami H, Tanaka K, et al. Clinical effects of acrylic resilient denture liners applied to mandibular complete dentures on the alveolar ridge. J Oral Rehabil. 2007 Nov; 34(11):862–9.

49) Onuma H, Inokoshi M, Hirayama D, Inoue M, Minakuchi S. Stress distribution analysis of oral mucosa under soft denture liners using smoothed particle hydrodynamics method. J Mech Behav Biomed Mater. 2021 May 1; 117.