INDONESIAN JOURNAL OF PROSTHODONTICS

REVIEW

Strain distribution on shortened dental arches complete denture using finite element analysis

Jasmine,[1] Ariyani,[2]* Ismet Danial Nasution[2]

Keywords: Complete denture, Finite element analysis, Shortened dental arches, Strain distribution analysis

ABSTRACT

Prosthetic management for edentulism could be challenging with the Inadequate interocclusal space due to enlargement of the maxillary tuberosity, causes difficulties in artificial tooth placement. Hence, reducing numbers of artificial teeth is indicated which is in line with the shortened dental arches (SDA) concept. The SDA concept could provide good occlusal and mandibular stability, comfort in mastication and appearance. An increase in strain distribution value in the anterior region of the mandible was found in the SDA due to partial changes of the occlusal load distribution pattern. Strain distribution can be analyzed using Finite Element Analysis (FEA). This literature review aims to analyse the strain distribution on SDA complete denture using finite element analysis. The SDA concept was aimed at preserving the anterior and premolar regions. Masticatory ability is correlated with the number of teeth and is impaired if there are less than 20 teeth. Based on FEA, the increase in strain distribution value in the SDA concept is due to changes in occlusal load distribution pattern, masticatory muscle activity and tissue morphology that is susceptible to stress. Nevertheless, the strain value in SDA models were of lower intensity than the yield reported to cause deterioration effects. In maxillary complete denture, the highest strain value was found at the incisal and labial frenal notches. Strain distribution on shortened dental arches using finite element analysis shows a satisfactory masticatory ability and an increase in the value of stress distribution in the anterior region of the mandible. (IJP 2024;5(2):107-110)

Introduction

Prosthetic management of edentulism can be challenging with the presence of limited interocclusal space. This condition is caused by prolonged edentulous state which create extrusion of opposing teeth combined with alveolar extrusion such as maxillary tuberosities overgrowth.[1] In result, inadequate interocclusal space makes difficulty in complete denture fabrication especially on the artificial teeth placement. Surgical intervention like maxillary tuberosities reduction could solve the problem. However, there are times when surgery is not judicious.[2] Hence, reducing numbers of artificial teeth in complete denture fabrication is indicated which is in line with the shortened dental arches (SDA) concept.

SDA is defined as having an intact anterior region but a reduced number of occluding pairs of posterior teeth.[3] This concept was aimed at preserving the anterior and premolar region. Masticatory ability is correlated with the number of teeth and is impaired if there are less than 20 teeth and this statement are supported too by the World Health Organization whom indicates that a functional, aesthetic, natural dentition has at least 20 teeth.[3]

Finite element analysis (FEA) is one of the research tools that has become increasingly popular in dental research for biomechanical analysis due to its simplicity and reproducibility. It allows simple measurements to be made on models with complex geometries, provides information about the state of overall stress in the models, and enables quantitative study of the effect of force application.[4] FEA have been successfully applied to analyse the effects of different occlusal forces on tooth positioning and occlusal stability on complete dental arch.[5] Knowing that there are still lack of studies on SDA complete dentures, the use of FEA may improve understanding of the stress distribution on the SDA complete dentures. This literature review aims to discuss the strain distribution on SDA complete denture using finite element analysis.

Literature Studies

Complete Denture

Complete denture is a fixed or removable dental prosthesis that replaces the entire dentition and associated structures of the maxillae or mandible.[6] The foundation of complete denture is made up of bone and covering soft tissues. The denture base rests on the mucous membrane, which serves as a cushion between the denture base and the supporting bone. The goal on fabricating complete denture includes maximizing the extension of the denture base increases surface area and spreads the "pressure" of mastication and tooth contacts during swallowing over a greater surface area. These involve capturing the anatomical landmark of both maxilla and mandibula, compromising two areas: stress-bearing (or supporting) area and peripheral (or limiting) area.[7]

The maxillary tuberosity is one of the maxilla anatomical

1Specialist Program in Prosthodontics, Faculty of Dentistry, Universitas Sumatera Utara, Medan, Indonesia
2Department Prosthodontics, Faculty of Dentistry, Universitas Sumatera Utara, Medan, Indonesia
*Corresponding author: ariyanidrg@yahoo.com

DOI 10.46934/ijp.v5i2.223

Table 1. Number of occluding pair of teeth required based on age

Age	Functional Level	Occluding Pair
20-50	I - Optimal	12
40-80	II - Suboptimal	10 (SDA)
70-100	III - Minimal	8 (ESDA)

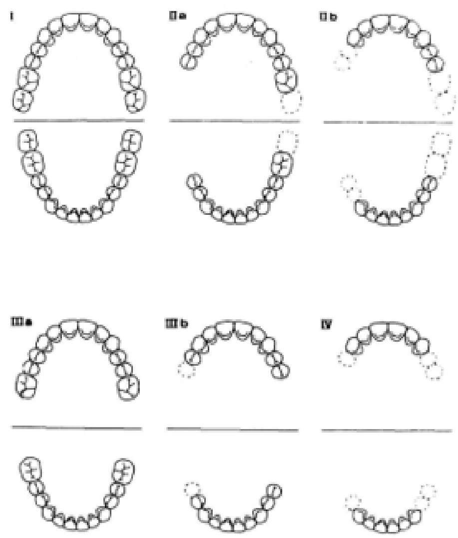

Figure 1. Schematic representation of SDA Classification

landmarks which offer considerable support on denture as it consists of dense fibrous connective tissues with minimal compressibility.[7] It is located in the posterior inferior extension of the maxillary bone, bounded mesially by the last erupted molar and maxillary sinus, and distally by the pterygopalatine fissure and pyramidal process of the palatine bone.[8]

Enlarged maxillary tuberosities, which may consist of soft tissue, bone or both, may be caused by combination syndrome or so called Kelly's syndrome and extrusion of maxillary posterior teeth and alveolar associated with an untreated Kennedy class 1 type of mandibular dentition.[7,9]

Excesses in the area of the maxillary tuberosity may encroach on the interocclusal space and decrease the overall freeway space needed for proper prosthetic function.[10] When the maxillary tuberosities are so large that they prevent the correct location of the occlusal plane, require the omission of some teeth, or prevent the correct distal extensions of the denture bases.[7] Surgical intervention like maxillary tuberosities reduction could solve the problem. However, there are times when surgery is not judicious, especially on elderly and medically compromised patient.[2] Hence, reducing numbers of artificial teeth in complete denture fabrication is indicated which is in line with the shortened dental arches (SDA) concept.

Shortened dental arches (SDA)

The term 'shortened dental arches' (SDA) was first used in 1981 by the Dutch prosthodontist Arnd Kayser for a dentition with loss of posterior teeth.11 The SDA is defined as having an intact anterior region but a reduced number of occluding pairs of posterior teeth. This concept was aimed at preserving the anterior and premolar region.[3]

SDA has been classified into five classes:[1] IIa – asymmetrical (3–4 pre-molars and 1–2 molars); IIb – asymmetrical (2–3 pre-molars and 1 molar); IIIa – symmetrical (3–4 pre-molars and 2 molars); IIIb – symmetrical (3–4 pre-molars); IV – extremely shortened (0–2 premolars and no molars).

Table 1 suggests minimum number of occluding pair of teeth required based on age and other factors to provide satisfactory levels of oral function.[12]

Masticatory ability is correlated with the number of teeth and is impaired if there are less than 20 teeth. Kayser estimated the minimum number of teeth needed to satisfy functional demands of modern man:[11] Biting: 12 front teeth + 4 premolars; Mastication: 8 premolars + 4 molars; Speech: 12 front teeth; Aesthetics, 12 front teeth + 4 premolars in the maxilla; Mandibular stability: 12 front teeth + 8 premolars + (4 molars in some cases).

SDA may be appropriate for patients meeting the following criteria:[12] Progressive caries and periodontal disease confined mainly to the molars; Good long term prognosis for the anterior teeth; Financial and other limitations to dental care.

The contraindications of SDA include:[12] Severe maxillomandibular discrepancy (e.g. Severe angle class II and class III relationship); Anterior open bite; Parafunctional habits; Pre-existing craniomandibular dysfunction; Marked pathological tooth wear; Marked reduction in alveolar bone support (e.g. advanced periodontal disease); Patient below 50 years of age.

Probable advantages of SDA are:[12] Simplification of extensive restorative management; Easier maintenance for both the patient and the dentist; Simplification of oral hygiene maintenance; Good prognosis for the remaining teeth. if the patient learns to maintain his/her own dentition.

The prognosis on SDA depends on:[12] Maintenance of good oral health; The maxillomandibular jaw relationship; The age of the patient; The periodontal status of the anterior and premolar teeth; The adaptive potential of the TMJ; Occlusal stability.

The SDA concept could provide good occlusal and mandibular stability, comfort in mastication and appearance. Sufficient adaptive capacity in subjects with SDA achieved when at least four occlusal units are left (one unit corresponds to a pair of occluding premolars; two units correspond to a pair of occluding molars).[11]

The World Health Organization too indicates that a functional, aesthetic, natural dentition has at least 20 teeth, provided a strong support by suggesting that the SDA concept was a possible clinical alternative in certain conditions.[11]

Strain distribution

Strain, or the change in length per unit length, is the relative deformation of an object subjected to a stress. Strain may be either elastic, plastic, elastic and plastic. or viscoelastic. Elastic strain is reversible where the object fully recovers its original shape when the force is removed. Plastic strain represents a permanent deformation of the material while viscoelastic materials deform by exhibiting both properties (viscous and elastic characteristic) and a time dependent strain behavior.[13]

Strain distribution analysis allow further understanding of transmitted stress to the underlying structures to denture bases where excessive stress may result in denture failure such as denture bases deformation.[14]

Various methods can be used to study stress distribution in dentures such as brittle lacquer coatings, strain gauges, photoelasticity, holography, mathematical equations, and finite element analysis (FEA). Among all these methods, FEA has become increasingly popular for stress analysis due to its improved simplicity and reproducibility.[4]

Finite element analysis

Finite element analysis (FEA) is one of the research tools that has become increasingly popular in dental research for biomechanical analysis due to its simplicity and reproducibility. It allows simple measurements to be made on models with complex geometries, provides information about the state of overall stress in the models, and enables quantitative study of the effect of force application.[4] FEA have been successfully applied to analyse the effects of different occlusal forces on tooth positioning and occlusal stability on complete dental arch.[5]

Discussion

The FEA method has been established as a standardised scientific procedure for qualitative assessment of the stress distribution in various structures, and it has been used to evaluate the stress distribution underneath the complete denture in the residual alveolar bone.[15]

FEA study on conventional maxillary complete denture by Cheng et al showed that the highest tensile and compressive strains were found at the incisal notches and labial frenal notches, respectively. These results agreed with the findings of Matthew and Wain using brittle lacquear coating found that crack lines in anterior palate of intaglio surface originated from the tip of the incisal notch. The high tensile strain concentration at the incisal notch is likely to be the cause of denture fracture during clinical service. One of the most likely reasons on crack initiation and propagation in incisal notch which result faster rate of denture fracture is the repeated high occlusal load by the opposing natural dentition. On the other hand, Hargreaves observed that a deep labial frenal notch was the cause of midline fracture due to high tensile strain and labial frenectomy is advised to reduce the strain concentration.[4]

Literature indicates that masticatory ability closely correlates with the number of teeth and is impaired when there are fewer than 20 uniformly distributed teeth in the mouth.[3] In the study of dentate a shortened dental arch does not affect masticatory efficiency and might be suggested as an alternative treatment. This statement is further supported by the research of Iegami et al where in complete denture wearers, the absence of second molars also did not affect masticatory efficiency, despite the reduction in occlusal area.[1]

In terms of number of occluding pair of teeth and mastication in dentate subject, it was concluded that SDA with intact premolar regions and at least one occluding pair of molars provided sufficient chewing ability. The chewing ability deteriorated with a decrease of occluding pairs of teeth, especially for hard foods. Subjects with extreme SDA (0 to 2 occluding premolars) complained of severely reduced chewing ability.11 Likewise, subjects with asymmetric arches and unevenly distributed teeth reported greater masticatory difficulty than subjects with more complete dental arches.[3]

FEA study in dentate subject revealed that shortening the dental arch partially changed the pattern of occlusal load distribution and increased stress and strain in the anterior mandibular segment as the occlusal loading shift anteriorly. A location of the areas of higher stress despite associated with the loading position, site and the morphology of the material or tissue is also susceptible to stress. Nevertheless, the strain value in SDA models were of lower intensity than the yield reported to cause deterioration effects.[16,17]

Conclusion and Suggestion

The SDA concept is an example of problem-oriented approach and could be implemented in complete denture fabrication to manage reduced interocclusal space caused by enlarged tuberosities without the need of surgical intervention. With the minimum of 20 occluding units, it could provide good occlusal and mandibular stability, comfort in mastication and appearance. FEA study in dentate subject revealed that shortening the dental arch partially changed the pattern of occlusal load distribution and increased stress and strain in the anterior mandibular segment.

The use of FEA can improve understanding and help describing how the strain distribution on the denture base, and the result allow the outlook of possible risk of SDA complete denture bases complications in the future. Knowing that there is still limited study conducted on SDA complete denture, therefore, more studies are needed to assess stress distribution on SDA complete denture for the application on theoretical and clinical scopes.

References

1. Iegami CM, Barbosa WF, Furuyama RJ, Lima JRB, de Campos TT, Minagi S, et al. Masticatory efficiency in complete denture wearers with reduced dental arches - a randomised cross-over study. J Oral Rehabil. 2014;41(8):619–23.
2. Bell RA, Richardson A. Prosthodontic treatment of pendulous maxillary tuberosities. J Am Dent Assoc. 1981;103(6):894–5.
3. Armellini D, Anthony Von Fraunhofer J. The shortened dental arch: A review of the literature. Journal of Prosthetic Dentistry. 2004;92(6):531–4.
4. Cheng YY, Cheung WL, Chow TW. Strain analysis of maxillary complete denture with three-dimensional finite element method. J Prosthet Dent. 2010;103(5):309–18.
5. Franco B, Oliveira D, Seraidarian PI, Gomes De Oliveira S, Landre J, Melo Pithon M, et al. Tooth displacement in shortened dental arches: A three-dimensional finite element study. 2013;1–6.
6. Ferro KJ, Morgano SM, Editor Carl Driscoll CF, Freilich MA, Guckes AD, Knoernschild KL, et al. THE GLOSSARY OF PROSTHODONTIC TERMS. J Prosthet Dent. 2017 May;117(5S):28.
7. Zarb G, Hobkirk JA, Eckert SE, Jacob RF. Prosthodontic Treatment for Edentulous Patient. 13th ed. St Louis: Mosby; 2013. 69,116.
8. Dan Vardimon A, Shoshani K, Shpack N, Reimann S, Bourauel C, Brosh T. Incremental growth of the maxillary tuberosity from 6 to 20 years-A cross-sectional study. Arch Oral Biol. 2010;55(9):655–62.
9. Tolstunov L. COMBINATION SYNDROME: CLASSIFICATION AND CASE REPORT. Journal of Oral Implantology [Internet].

DOI 10.46934/ijp.v5i2.223

2007;33(3):138. Available from: http://meridian.allenpress.com/joi/article-pdf/33/3/139/2034487/1548-1336
10. Miloro M. Peterson's Principles of Oral and Maxillofacial Surgery. 3rd ed. 2011. 136 p.
11. Kanno T, Carlsson GE. A review of the shortened dental arch concept focusing on the work by the Käyser/Nijmegen group. Vol. 33, Journal of Oral Rehabilitation. 2006. p. 850–62.
12. Fernandes V, Chitre V. The shortened dental arch concept: A treatment modality for the partially dentate patient. Vol. 8, Journal of Indian Prosthodontist Society. 2008. p. 134–9.
13. Anusavice KJ SCRH. Phillips' Science of Dental Materials. 12th ed. Phillips' Science of Dental Materials. St. Louis: Elsevier Saunders; 2013. 98–99 p.
14. Takahashi T, Gonda T, Tomita A, Mizuno Y, Maeda Y. Influence of Palatal Coverage and Implant Distribution on Denture Strain in Maxillary Implant Overdentures. Int J Oral Maxillofac Implants. 2016 May;e43–8.
15. Chowdhary R, Lekha K, Patil NP. Two-dimensional finite element analysis of stresses developed in the supporting tissues under complete dentures using teeth with different cusp angulations. Gerodontology. 2008 Sep;25(3):155–61.
16. Milić-Lemić A, Tanasić I, Tihaček-šojić L. Stress and strain distribution in the lower jaw with shortened dental arch – A finite element method study. Srp Arh Celok Lek. 2018;146(11–12):629–33.
17. Alhmoudi H, Khamis AH, Elbishari H, Amir-Rad F. The Shortened Dental Arch Concept: Awareness, Knowledge, and Practice of Dentists in Dubai and the Northern Emirates, United Arab Emirates. Int J Dent. 2022;1–2.

DOI 10.46934/ijp.v5i2.223