J Indian Prosthodont Soc (July-Sept 2013) 13(3):212–219
DOI 10.1007/s13191-012-0193-y

ORIGINAL ARTICLE

Comparison of Stress Dissipation Pattern Underneath Complete Denture with Various Posterior Teeth form: An In Vitro Study

N. Mankani · R. Chowdhary · S. Mahoorkar

Received: 14 February 2012 / Accepted: 10 October 2012 / Published online: 20 November 2012

Abstract To evaluate the pattern of stress dissipation underneath the complete denture with various angled posterior teeth in both maxillary and mandibular arch. A 3D finite element models of residual ridge, mucosa, denture base in the coronal section were created from the dentures obtained from a patient, which were scanned and modeled. The coronal portion of the teeth was altered to stimulate the cuspal inclination of 0°, 20° and 33°, thus making the models. Special area of interest in bone, denture were selected to record the stresses. An vertical static load of 100N was applied through the mandibular model to the maxillary model. von Mises stresses developed in all the models were interpreted. Statistical analysis for comparison of stress values with different variables (0°–20°, 0°–33°, and 20°–33°) in various predefined areas of coronal section model was done using Student's *t* test (paired). Stress of greater magnitude were observed with cuspal teeth i.e. 33° and 20°, where as 0° showed slightly less magnitude of stresses.

Keywords Complete denture · Cuspal inclination · Stress dissipation

N. Mankani
Department of Prosthodontics, P. M. Nadagowda Dental College, Bagalkot, India
e-mail: drniveditam@yahoo.co.in

R. Chowdhary (✉) · S. Mahoorkar
Department of Prosthodontics, S. Nijalingappa Institute of Dental Sciences and Research, Gulbarga 585105, India
e-mail: drramc@yahoo.com

Introduction

Natural dentition sustains the forces of mastication adequately. However, when lost either through caries, trauma, or periodontal disease artificial substitutes are sought to provide a comparable aesthetic and functional result. Dentures are used as artificial substitutes when a number of teeth are missing. In order to provide optimum function they must withstand the stresses and strains encountered from masticatory loads and para functional activities [1].

Considerable interest has been shown in the measurement of force exerted during mastication, with both natural and artificial dentitions [2]. The occlusal surfaces of the natural dentition as well as those of the complete dentures should ideally have similar occlusal morphology in relation to the foundation. Therefore, many types of occlusal forms and posterior tooth arrangements have been used in complete dentures for almost 200 years. Some of these occlusal schemes have clinically evaluated. Research in this field has been directed towards three factors: (i) masticatory efficiency [1–7] (ii) forces directed to the residual ridges [8–15], and (iii) patient comfort [16, 17]. The three major groups of occlusal form available are (1) anatomic- 30° cusps; (2) semi anatomic- 20° cusps; (3) non anatomic or cuspless 0° cusps [4]. Investigators have shown considerable interest in the measurement of forces exerted during mastication with both natural and artificial dentitions [3–5, 14]. The understanding of these forces and the pattern of stress distribution in the bone underneath the complete denture are of prime importance when planning denture fabrication. Neglect of these factors may result in unnecessary discomfort to the denture wearer and cause alveolar ridge resorption. Finite element analysis is an computerized numerical method used to determine the distribution of stresses and displacements in a structure subjected to mechanical load. Initially developed for use in the aircraft industry. Since its introduction the method has seen application not only to biomechanics, but also to dentistry [18].

The objective of this study was to evaluate the pattern of stress dissipation underneath the complete denture with various angled posterior teeth in both maxillary and mandibular arch.

Materials and Methods

To design these study models, the contour of the denture was obtained from a patient's complete maxillary and mandibular complete denture. This was sliced through the mesial aspect of the denture in the first molar region. The external contours were digitized in Unigraphics UGNX4 (Unigraphics Inc., USA) (Fig. 1) and then transferred to finite element program ANSYS 10.0(ANSYS Inc., PA, USA). The maxillary and mandibular frontal section models were designed separately and 3 mm of space was kept between the models (Fig. 2). This was created to simulate inter arch space in the oral cavity. This frontal section of maxillary and mandibular was duplicated and similar two more pairs of maxillary and mandibular complete denture models were designed and occlusal aspect of all the three upper and lower models were altered to appropriate the required 33° (Anatomic), 20° (Semi anatomic) and 0° (monoplane) cuspal teeth and their intercuspation were checked (Fig. 3). The geometric model was meshed, the design consist of 8-noded hexahedron brick

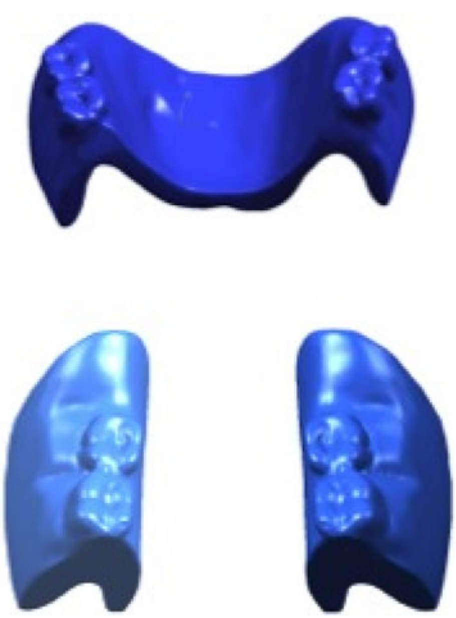

Fig. 1 CAD_CAM image of coronal section of patient's maxillary and mandibular complete denture in the first molar region

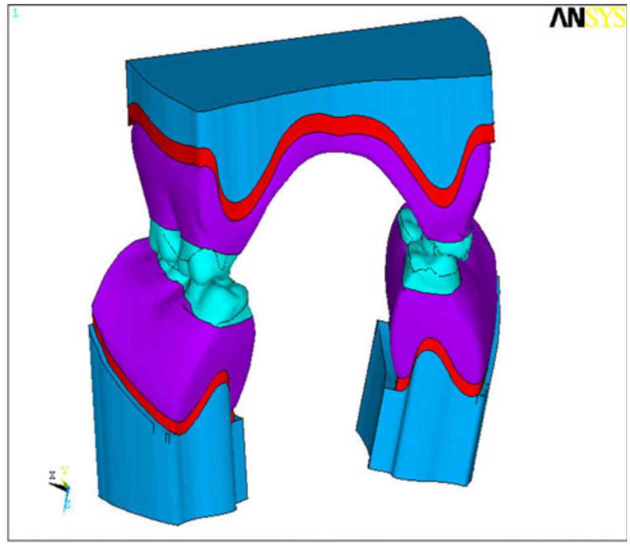

Fig. 2 FEA model of maxillary and mandibular complete denture in first molar region showing the underlying mucosa and alveolar bone

solid 45 element with 3° of freedom and the other 3-D models were meshed with 8-noded quadrilateral plane strain elements (Fig. 4). All models were assumed to behave like a slice on the symmetry axis of the denture, thus enabling 2D analysis with plane-strain element (strain in direction of the slice normal is forced to be zero) (Fig. 4).

The 3D FEA of residual ridge, mucosa, denture base and 20° teeth included 528261 elements for mandibular model and 564283 elements for maxillary model. The bone was assumed to be isotropic, homogenous and linearly elastic. The materials and their properties used in the model are shown in Table 1. These values were determined from the literature using FEA model of human jaws [19–21]. Considering the chewing force for denture wearers to be in the range of 50–100N [12, 20–23] a vertical static load of 100N was applied through the base of the mandibular models (Fig. 5). This represented the normal occlusal load that was recorded in the molar region of a complete denture [2, 3].

The FEA revealed stresses and deformation at different nodes in the models. As it is cumbersome to report all of the information, result are generally displayed as stress contours overlaid on the original models. This type of display permitted the detection of maximum stresses and stress concentrations for the entire model.

However, in the regions of special interest, the absolute values of stresses were determined. These areas were, below the denture in mucosa over the crest: (a) crest of the ridge, (b) buccal slope of the ridge, (c) lingual slope of the ridge, (d) below the crest, in alveolar bone, (e) and the alveolar bone proper, (f) (Fig. 6). In the mandibular section, they were marked as a^1, b^1, c^1, d^1, e^1, and f^1, respectively (Table 1).

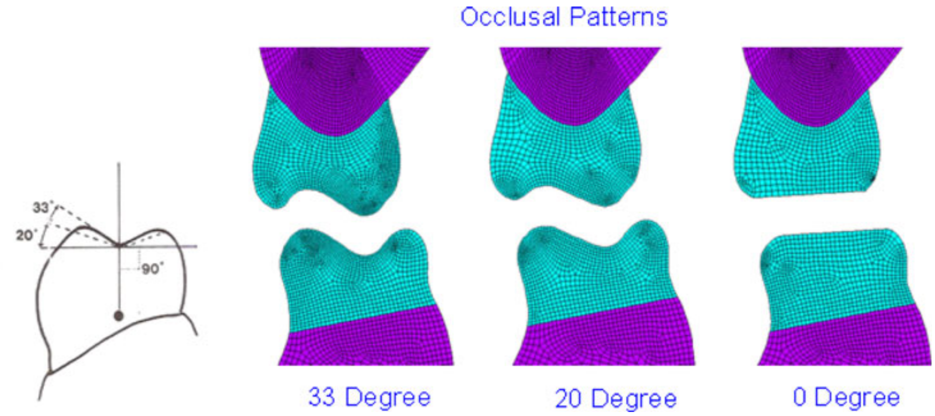

Fig. 3 FEA models various occlusal pattern

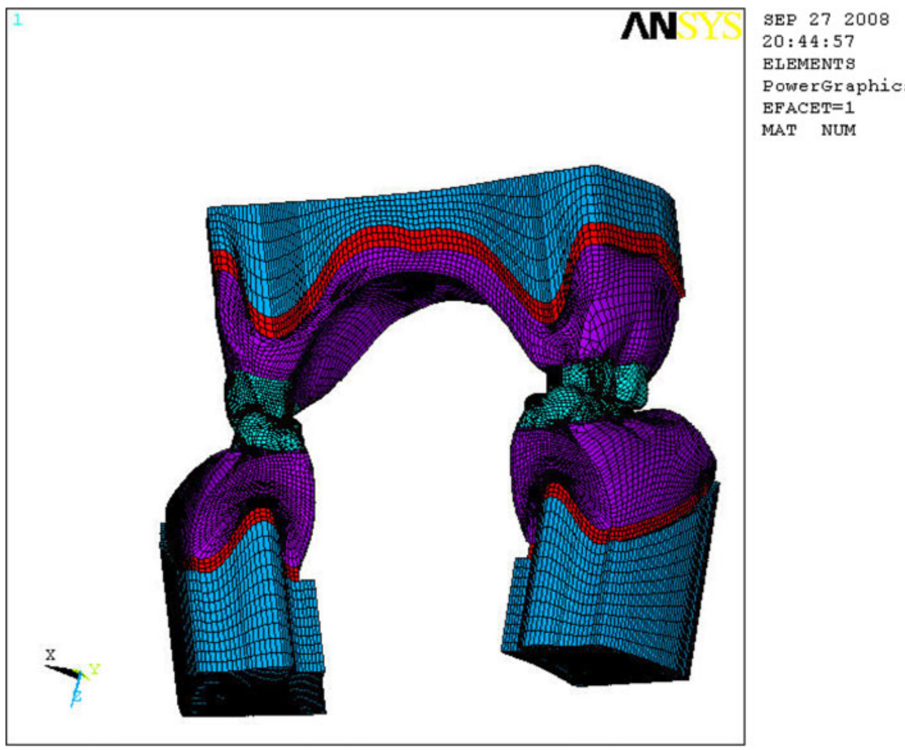

Fig. 4 3D FEA model of maxillary mandibular complete denture with mesh

Table 1 The materials used in the study models and their properties

Material	Young's modulus (MPa)	Poisson's ratio
Bone	13,500	0.3
Mucosa	7.5	0.45
Denture base	1960	0.3
Artificial teeth of acrylic	2,940	0.3

Results

The results were interpreted as von Mises stresses. The stresses Developed were observed in all the models (Figs. 4, 5, 7). The specific characteristics of the resulting stress patterns varied with different types of posterior teeth (Figs. 8, 9). The stress patterns observed within the model with type of posterior occlusion, showed unique variations as well as some similarities (Tables 2, 3). Greater stress values were observed in the 20° and 33° cuspal teeth than in 0° teeth. Statistical analysis for comparison of stress values with different variables (0°–20°, 0°–33°, and 20°–33°) in various predefined areas of coronal section model was done using Students *t* test (paired), for mandibular and maxillary models separately. The cuspal and non cuspal teeth were compared with each other and the analysis obtained were tabulated and their statistical significance was determined (Tables 2, 3). From the results of these predefined areas, it was statistically interpreted that stress values of 0°–20° and 0°–33° on comparison with each other significant, when compared to the values of comparison between 20° and 33°. Most of 20°–33° comparisons showed non-significant values.

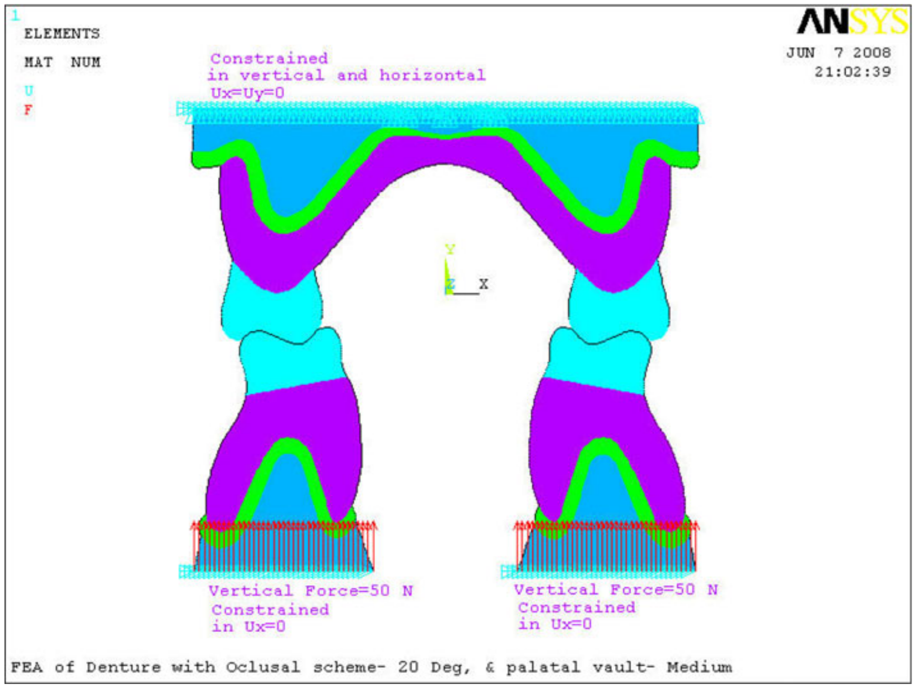

Fig. 5 FEA model with load application

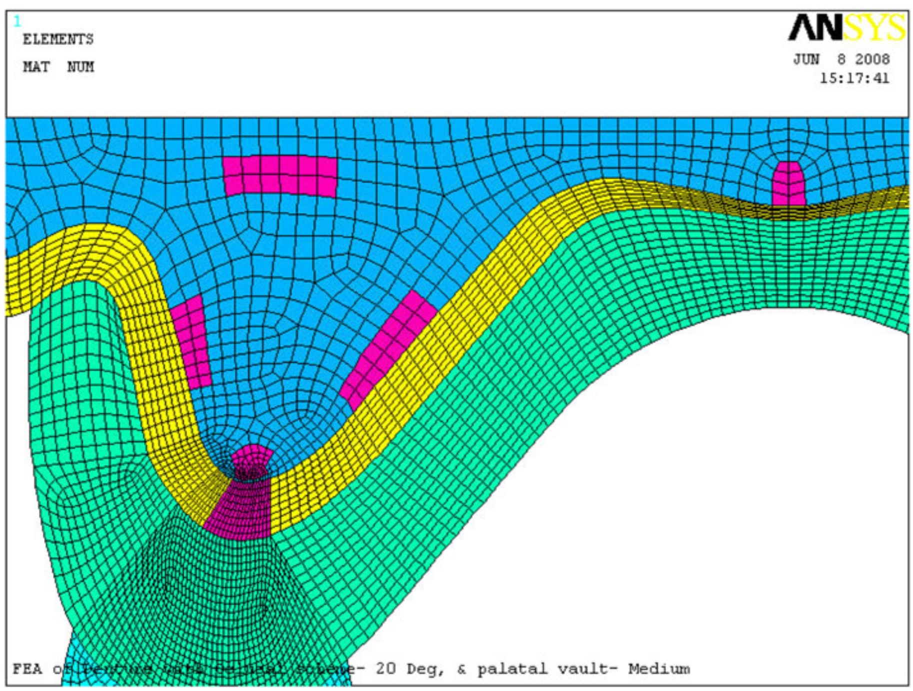

Fig. 6 Predefined areas selected in maxillary model (similar positions were selected in mandibular as predefined areas)

Discussion

Maintenance of the supporting tissues in a physiologic condition is a Prime requisite when constructing an oral prosthesis. In spite of the best clinical efforts. However, the underlying supporting tissues often undergoes degenerative changes. In some cases, the general health and nutritional status of the patient are felt to be the causative factors. In others, these changes are felt to be caused by the unequal distribution of functional forces [24]. The edentulous

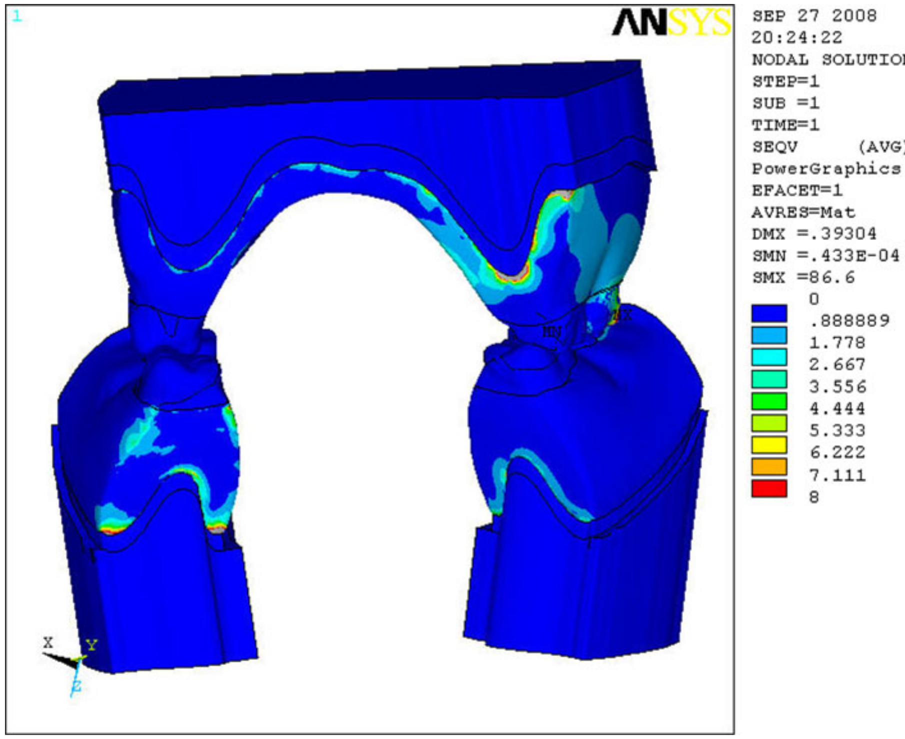

Fig. 7 von Mises stress analysis of 3D FEA models of maxillary and mandibular complete denture with 20° occlusal pattern

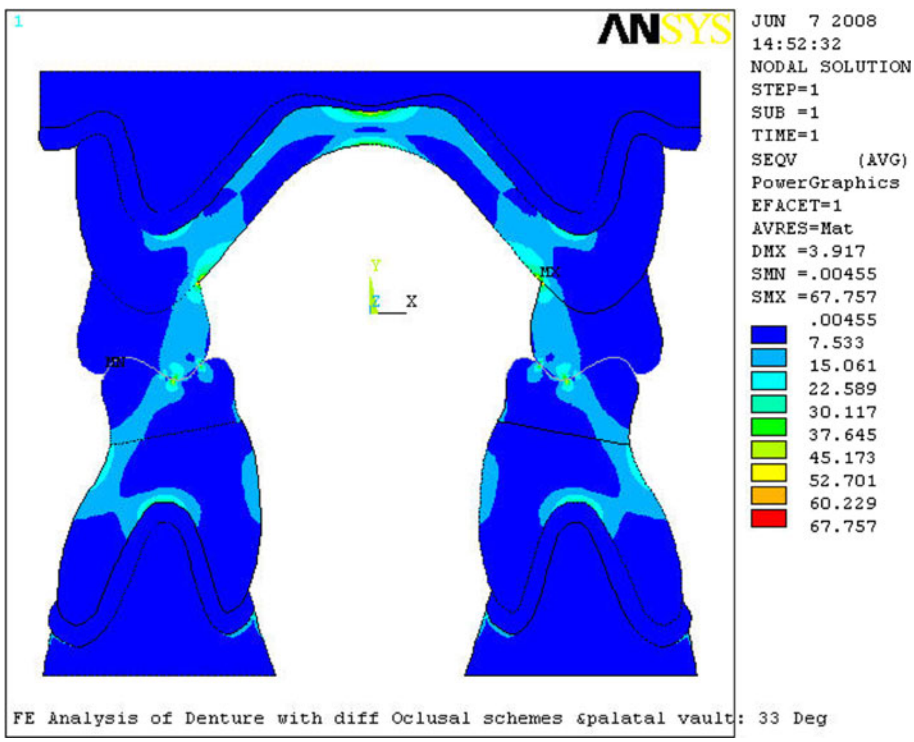

Fig. 8 von Mises stress analysis of maxillary and mandibular complete denture FEA models with 33° occlusal pattern

mandible is not structurally capable of withstanding forces that the dentoalveolar attachment apparatus dissipated effectively. Dentist have been aware of this problem and have developed numerous philosophies about tooth form, tooth materials, and placement of teeth [25].

Several studies concerning the stress pattern underneath the Complete dentures in residual alveolar bone have been carried out through various methods like complete dentures in residual alveolar bone have been carried out through various methods like electrical strain gauges, photoelastic

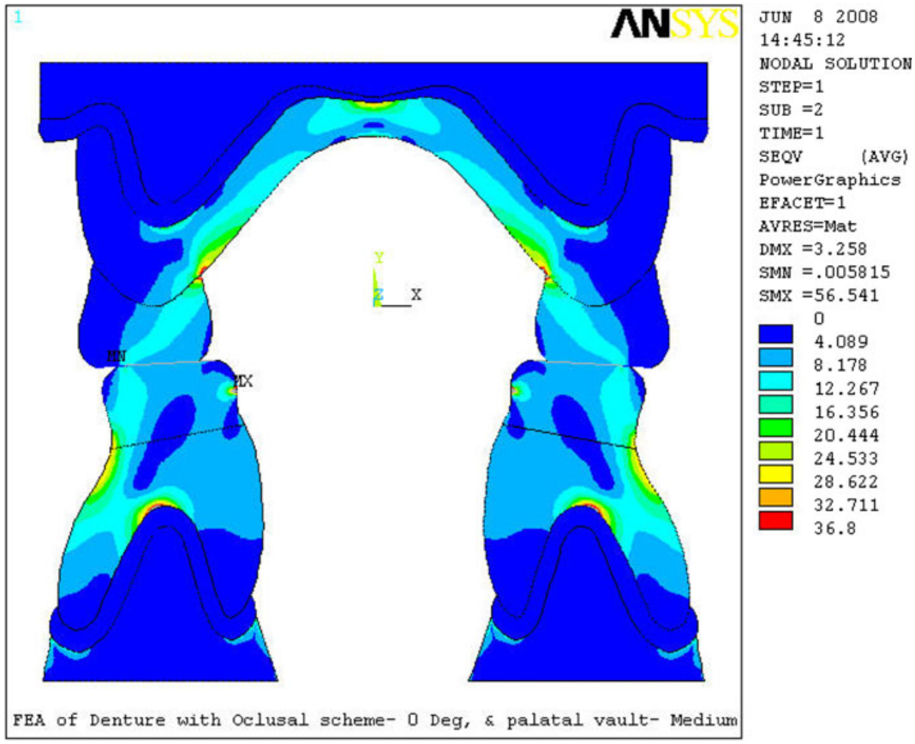

Fig. 9 von Mises stress analysis of maxillary and mandibular complete denture FEA models with 0° occlusal pattern

Table 2 Statistical analysis for comparison of stress values in various pre-defined area between Monoplane 20° and 33° for coronal section

Mandibular model

Between	Statistics	a	b	c	d	e	f
Monoplane and 20° teeth	Mean	0.8633	1.8533	0.7567	2.6767	2.1867	1.5867
		0.8503	1.8533	2.0067	0.5733	2.1067	1.6667
	SD	0.0544	0.0377	0.0205	0.0125	0.0262	0.0464
		0.0959	0.0411	0.0772	0.0573	0.0736	0.0386
	t value	0.1669	0	22.1631	1.0458	1.4493	−1.8735
	p value	>0.05	>0.05	>0.001	>0.05	>0.05	>0.05
	Significance	NS	NS	NS	NS	NS	NS
Monoplane and 33° teeth	Mean	0.8633	1.8533	0.7567	2.6767	2.1867	1.5867
		0.8503	1.8533	2.0067	0.5733	2.1067	1.6667
	SD	0.0544	0.0377	0.0205	0.0125	0.0262	0.0464
		0.0959	0.0169	0.0092	0.0262	0.0624	0.0713
	t value	0.1669	0.5685	11.3774	0	−2.0167	−2.2691
	p value	>0.05	>0.05	>0.001	>0.05	>0.05	>0.05
	Significance	NS	NS	NS	NS	NS	NS
20° teeth and 33° teeth	Mean	0.8503	1.8533	2.0067	2.5733	2.1067	1.667
		0.8503	1.8367	1.987	2.6767	2.2833	1.7233
	SD	0.0959	0.0411	0.0772	0.0573	0.0736	0.0386
		0.0959	0.0169	0.0092	0.0262	0.0624	0.0713
	t value	0	0.5287	0.3588	−2.3184	−2.5894	−0.9878
	p value	>0.05	>0.05	>0.05	>0.05	>0.05	>0.05
	Significance	NS	NS	NS	NS	NS	NS

NS no significance

Table 3 Statistical analysis for comparison of stress values in various pre-defined area between Monoplane 20^0 and 33^0 for coronal section

Maxillary model

Between	Statistics	a^1	b^1	c^1	d^1	e^1	f^1	g
Monoplane and 20° teeth	Mean	0.3667	1.13	2.3567	1.4633	1.79	1.2267	2.3667
		0.537	1.7467	3.63	2.229	2.6167	1.9733	1.3473
	SD	0.0464	0.0496	0.1601	0.0464	0.0294	0.0573	0.0324
		0.0156	0.0339	0.1023	0.0342	0.0785	0.1268	0.0238
	t value	−4.9219	−14.5106	−9.4810	−18.7672	−13.9409	−7.5874	35.5191
	p value	<0.01	<0.001	<0.001	<0.001	<0.001	<0.01	<0.001
	Significance	S**	HS	HS	HS	HS	S**	HS
Monoplane and 33° teeth	Mean	0.3667	1.13	2.3567	1.4633	1.79	1.2267	2.3667
		0.5273	1.6567	3.7833	2.25	2.41	1.34	1.388
	SD	0.0464	0.0496	0.1601	0.0464	0.0294	0.0573	0.0329
		0.0197	0.03219	0.0624	0.0356	0.1236	0.2142	0
	t value	−4.5112	−12.5107	−11.7416	−19.0024	−6.9042	−0.7226	42.004
	p value	<0.05	<0.001	<0.001	<0.001	<0.01	>0.05	<0.001
	Significance	S*	HS	HS	HS	S**	NS	HS
20° teeth and 33° teeth	Mean	0.537	1.7467	3.63	2.229	2.6167	1.9733	1.3473
		0.5273	1.6567	3.7833	2.25	2.41	1.34	1.388
	SD	0.0156	0.0339	0.1023	0.0342	0.0785	0.1268	0.0238
		0.0197	0.0329	0.0624	0.0356	0.1236	0.2142	0
	t value	0.5449	2.6946	−1.8099	−0.6017	1.9971	3.5983	2.4226
	p value	>0.05	>0.05	>0.05	>0.05	>0.05	<0.05	<0.05
	Significance	NS	NS	NS	NS	NS	S*	S*

NS no significance, *S** significance at 5 % level, *S*** significance at 1 % level, *HS* highly significance

models and finite element analysis [24, 26–28]. Some of them have dealt to examine both mandibular and maxillary denture base rigidity and denture deformation [24] and also pattern of oral forces on supporting tissues before and after rebasing in complete denture [26]. In a photoelastic study conducted by Stephen Lopuck et al. [25], revealed that flat occlusal scheme transmitted slightly less forces to the ridge than the cuspal forms did.

In this study, the predefined areas of maxillary models, b^1—crest of th residual, c^1—palatal slope of the ridge, d^1—lingual slope of the ridge, e^1—below the crest in the alveolar bone showed significantly high stress values with 20° and 33° when compared with same areas in monoplane teeth model. But when 20° and 33° were compared. Not much difference in stress pattern was observed in the predefined areas. This is in accordance with the study conducted by Inove et al. [5], where they concluded that in centric occlusion that the maxillary pressure values at the buccal area were greater than those at the palatal area. In the mandibular molar region, the pressure values at buccal slope were twice those at the lingual slope regardless of the scheme of occlusion. When the total amount of stresses recorded at various areas in maxillary and mandibular coronal model for all the three types of posterior teeth (Tables 2, 3). It showed that more stresses were generated in the mandibular model than in the maxillary model. This is in agreement with the findings of a photoelastic investigation conducted by Stephan Lopuck et al. [25], that the structural capability of the edentulous mandible makes it exceedingly difficult to resist the functional forces generated where in the denture bearing surface is reduced considerably compared to the maxillary edentulous ridge. This factor alone increases the actual force per unit to approximately two to three times than, that is distributed to the maxillary residual alveolar ridge resulting in higher magnitude of stress in mandibular foundation than in maxillary foundation [4].

On comparing the mean values of cuspal teeth with that of the monoplane teeth the values showed that, the magnitude of stress values were more in cuspal teeth i.e., 33° and 20°, respectively, than in the monoplane teeth indicating that more magnitude of stress was generated in cuspal teeth when compared to the monoplane teeth, when evaluated in coronal section model of the dentures having different cuspal angulations. Which agrees with the study conducted but Robert Rapp, that in monoplane teeth dentures, there is less resorption of ridge tissues due to less stress dissipation. Stephen Lopuck et al. [25] stated that in overall effect flat occlusal scheme transmitted slightly less force to the ridge than the cuspal (20° and 33° forms did [17]. A study by Sherry et al. [29], where in by using brittle coating lacquers also found that identical loads caused more deformation of bone beneath non anatomical tooth forms.

This variation in recorded stresses in different cuspal teeth models may be due to:

1. The change in the angulation of the occlusal pattern may change the direction of the forces.
2. As the angulation of the cusp increases the contact area of the tooth with opposing tooth is reduced.

Conclusion

Based on the observation and results of this study following conclusions were drawn:

1. Stress of greater magnitude were observed with cuspal teeth i.e. 33° and 20° where as monoplane teeth showed slightly less magnitude of stresses.
2. On analysis, the predefined areas showed variation of stress distribution among cuspal and monoplane teeth. The buccal slopes of the maxillary and mandibular models shoed higher stresses with cuspal teeth. Whereas least stresses were recorded with the monoplane teeth on both buccal and lingual slopes of maxillary and mandibular models.
3. More stresses were generated in the mandibular model than in the maxillary model.

References

1. Darbar UR, Huggett R, Harrison A (1994) Stress analysis technique in complete dentures. J Dent 22:259–264
2. Lawson WA (1960) The validity of a method used for measuring masticatory forces. J Prosthet Dent 10:99–111
3. Kelsy CC, Reid FD, Coplowitz JA (1976) A method of measuring pressures against tissues supporting functioning complete dentures. J Prosthet Dent 35:376–383
4. Clough HE, Knodle JM, Leeper SH, Pudwill ML, Taylor TD (1983) A comparison of lingualized occlusion and monoplane occlusion in complete denture. J Prosthet Dent 50:176–179
5. Inove S, Kawano F, Nagao K, Matsumoto N (1996) An in vitro study of the influence of occlusal scheme on the pressure distribution of complete denture supporting tissues. Int J Prosthodont 9:179–187
6. Frechette AR (1955) Comparison of balanced and non-balanced occlusion of artificial dentures based upon distribution of masticatory force. J Prosthet Dent 5(6):801–809
7. Takayama Y, Yamada T, Araki O, Seki T, Kawasaki T (2001) The dynamic behavior of a lower complete denture during unilateral loads: analysis using the finite element method. J Oral Rehabil 28:1064–1074
8. Mories JC, Khan Z, von Fraunhofer JA (1985) Palatal shape and the flexural strength of maxillary denture bases. J Prosthet Dent 53:670
9. Prombanas AE, Vlissids DS (2006) Comparison of the midline stress fields in maxillary and mandibular complete denture: a pilot study. J Prosthet Dent 95:63–70
10. El Ghazali S, Glantz PO, Strandman E, Randow K (1989) On the clinical deformation of maxillary complete dentures. Influence of denture base design and shape of denture-bearing tissue. Acta Odontol Scand 47:69–76
11. Dirtoft BI, Jansson JF, Abramson NH (1985) Using holography for the measurement of in vivo deformation in a complete maxillary denture. J Prosthet Dent 54:843–846
12. Prombanas AE, Vlissids DS (2002) Effects of the position of artificial teeth and load levels on the stress in the complete maxillary denture. J Prosthet Dent 88:414–422
13. Swoope CC, Kydd WL (1966) The effect of cusp form and occlusal surface area on denture base deformation. J Prosthet Dent 16:34–39
14. De Forest AV, Ellis G, Stern FB (1942) Brittle coating for quantitative strain measurements. J Appl Mech Trans ASME 64A:184–188
15. Mathews EM, Wain EA (1956) Stresses in denture bases. Br Dent J 100:167–171
16. Regli CP, Gaskill HL (1954) Denture base deformation during function. J Prosthet Dent 4:548–554
17. Rapp R (1954) The occlusion and occlusal patterns of artificial posterior teeth. J Prosthet Dent 4:548–554
18. Turner MJ, Clough RW, Martin HC, Top LJ (1956) Stiffness and deflection analysis of complex structures. J Aerosp Sci 23:805
19. Nishigawa G, Matsunaga T, Maruo Y, Okamoto M, Natsuaki N, Minagi S (2003) Finite element analysis of the effect of the denture supporting bone of the edentulous patient. J Oral Rehabil 30:646–652
20. Ates M, Cilinger A, Sulun T, Sunbuloglu E and Bozdag E (2006) The effect of occlusal contact localization on the stress distribution in complete maxillary denture. J Oral Rehabil 33:509–513
21. Atwood DA (1971) Clinical, cephalometric and densitometric study of the reduction of residual ridges. J Prosthet Dent 26:280
22. Kawano F, Koran III A, Asaoka K, Matsumoto N (1993) Effect of soft denture linear on stress distribution in supporting structures under a denture. Int J Prosthodont 6:43–49
23. Darbar UR, Huggett R, Harrison A (1995) Finite element analysis of stress distribution at the tooth denture base interface of acrylic resin teeth debonding from the denture base. J Prosthet Dent 74:591–594
24. Lambrecht JR, Kydd WL (1962) A functional stress analysis of the maxillary complete denture base. J Prosthet Dent 12(5):865
25. Lopuck S, Smith J, Caputo A (1978) Photoelastic comparison of posterior denture occlusion. J Prosthet Dent 40(1):18–21
26. Maeda Y, Wood WW (1989) Finite element method simulation of bone resorption beneath a complete denture. J Dent Res 68:1370–1373
27. Kydd WK ,Daly CH (1982) The biologic and mechanical effects of stress on oral mucosa. J Prosthet Dent 47:317–329
28. EMRC manual
29. Sharry JJ, Askaw HC, Hoyer H (1960) Influence of artificial tooth forms on bone deformation beneath complete dentures. J Dent Res 39:253–266