Theoretical Role of Adjunctive Implant Positional Support in Stress Distribution of Distal-Extension Mandibular Removable Partial Dentures

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This preliminary study evaluated the adjunctive supporting role of diverse implant positions on stress distribution in a Class I removable partial denture (RPD) design. Nine three-dimensional finite element models were prepared to simulate mandibular RPD designs with three different loading conditions applied. Implant-supported designs demonstrated lower stress value concentrations and mucosal displacement. *Int J Prosthodont 2014;27:579–581. doi: 10.11607/ijp.3866*

Implants may be placed bilaterally at distal-extension sites to convert a Kennedy Class I removable partial denture (RPD) into a Class III RPD. However, not all patients have sufficient bone volume in the posterior region, and an alternative solution is to place implants close to the anterior teeth instead of in the retromolar region. Resultant RPD designs may then be regarded as adjuncts to a cantilevered or shortened dental arch (SDA) design. This study used three-dimensional finite element analysis to study the influence of implant position on the stress distribution of combined teeth/implant support when designing Kennedy Class I RPDs.

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Materials and Methods

Measurements of mandible and teeth were taken (Advantage Workstation version 4.3, GE Healthcare), from the reconstructed images of a healthy male adult volunteer with satisfactory oral health using computed tomography scans (64-slice LightSpeed VCT, GE Healthcare). Nine mandible models (bilateral partially edentulous arches with only incisors, lateral incisors, and canines) were prepared by image-processing software GeoStar (COSMOS/M 2.85, SRAC). According to implant status (4.1 × 10 mm, soft tissue level, Straumann), models were divided into group N (without implant) and group I (with implant; Table 1 and Fig 1). The abutment connecting the RPDs and implant was a rigid telescopic crown (4 mm in height with 5 degrees of axial convergence), of which the inner crown was 0.5-mm thick.

Three different static load vectors (100 N vertical, 100 N at 45-degree inclination buccolingually, 20 N horizontally) were conducted on the center point of each simulated artificial tooth. This study focused on the maximum equivalent (EQV) stress value (in megapascals) in the periodontal membrane of the abutments (the canines), both cortical and cancellous bone around the implants, and mucosa under the distal-extension RPD. The maximum mucosa displacements (in millimeters) were observed at the posterior edge of the distal-extension RPD for all frameworks.

Results

Compared with traditional RPDs (Table 2: I1, I2, and I4 versus N1; I3 and I5 versus N2; I6 versus N3), RPDs with combined support reduced the stress values and displacements. Compared with a complete dental arch (Table 2: I6 and I3 versus I1), the SDA tended to

Table 1 Configuration of the Models

Model	Description
N1	Conventional distal-extension RPDs, with a classical rest, proximal plate, and Aker's clasp (RPA clasp) in the canines, replacing all premolars and first and second molars
N2	Conventional distal-extension RPDs, with a classical RPA clasp in the canines, replacing all premolars and first molars
N3	Conventional distal-extension RPD, with a classical RPA clasp in the canines, replacing all premolars
I1	Similar to N1, except with the implants located in the region of the second molars
I2	Similar to N1, except with the implants located in the region of the first molars
I3	Similar to N2, except with the implants located in the region of the first molars
I4	Similar to N1, except with the implants located in the region of the second premolars
I5	Similar to N2, except with the implants located in the region of the second premolars
I6	Similar to N3, except with the implants located in the region of the second premolars

N models = without implants; I models = with implants.

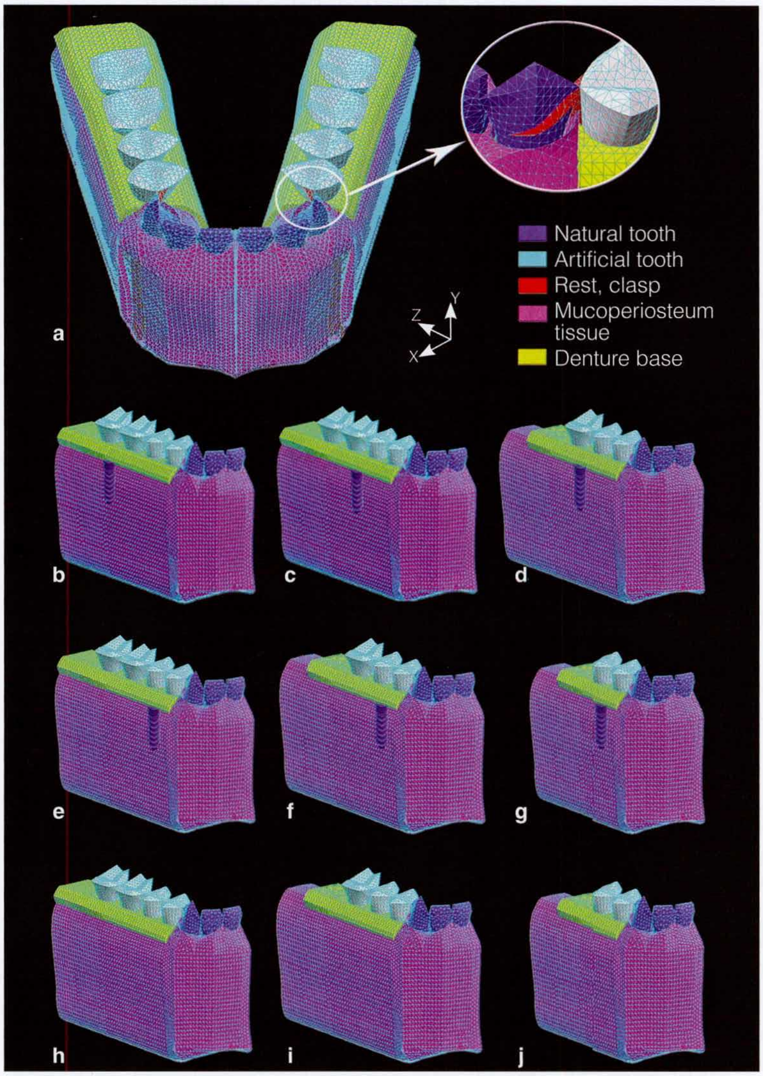

Fig 1 Three-dimensional finite element models: **(a)** Panoramic image of a model, **(b)** model I1, **(c)** model I2, **(d)** model I3, **(e)** model I4, **(f)** model I5, **(g)** model I6, **(h)** model N1, **(i)** model N2, **(j)** model N3. X = lingual direction; Y = axial direction; Z = mesial direction.

lower the maximum EQV stress values and displacements. Compared with no cantilever form (Table 2: I2 versus I1; I5 versus I3), the restoration of a one-unit cantilever resulted in the decrease of stress and displacement. Under vertical or horizontal loads, two-unit cantilevers (Table 2: I4) demonstrated the highest stress values and mucosa displacements.

Discussion

The observation that the presence of implants reduced the soft tissue intrusion of distal-extension RPDs was similar to that of published reports,[1-2] which suggested the merit of using anterior implant placement (closer to the most distal natural tooth abutment) to create an enlarged SDA or cantilevered restoration.

Compared with complete dental arch restoration, RPDs supported by a single implant unit demonstrated decreased stress values and mucosa displacements under vertical and oblique loading conditions. This observation was noted in the study of cross-arch fixed partial dentures.[3] It might be explained by the so-called counteract principle, whereby the implant acted as a fulcrum, and the compression tension on one side would produce a pull tension on the other side. This acted as a counterbalance[4] and a resultant decrease in the vector sum. Furthermore, a two-unit cantilever placement resulted in increased stress values and mucosa displacements. This might have been caused by the increased cantilever length. Under horizontal loads, the rule mentioned above was not observed in the restoration of a one-unit cantilever, probably because the fulcrum did not exist under this condition.

This preliminary report suggests that an RPD's arch length reduction had a positive effect on stress distribution and mucosa displacement. It may be presumed that such significant stress relief favors the concept of recruiting implant treatment to decrease risk of potential damage to remaining periodontal tissues and abutment teeth.

Table 2 The Maximum EQV Stress Values in Bone Around Implants, Periodontium of Canines, and Mucosa Under the RPD as Well as the Mucosal Displacement

Model	Load direction	Maximum EQV stress (MPa)				Mucosal displacement (mm)
		Cortical bone	Cancellous bone	Periodontium of canines	Mucosa under the RPD	
N1	Vertical	–	–	2.0136	0.4922	0.3346
	Oblique	–	–	7.2566	1.1748	0.8354
	Horizontal	–	–	1.6178	0.2635	0.2114
N2	Vertical	–	–	1.6537	0.2524	0.1773
	Oblique	–	–	6.5718	0.8169	0.5081
	Horizontal	–	–	1.4447	0.1774	0.1253
N3	Vertical	–	–	1.4625	0.1925	0.1276
	Oblique	–	–	5.2505	0.4627	0.2997
	Horizontal	–	–	1.1163	0.0982	0.0715
I1	Vertical	13.3557	1.2340	1.5874	0.2238	0.1518
	Oblique	46.9312	4.1913	4.8664	0.3617	0.2834
	Horizontal	10.0460	0.8831	1.1023	0.0688	0.0685
I2	Vertical	9.1627	0.9591	1.0922	0.1272	0.0855
	Oblique	37.3882	3.3975	3.8302	0.2634	0.2121
	Horizontal	11.204	0.9987	1.0075	0.0680	0.0690
I3	Vertical	9.1205	0.9724	1.1303	0.1285	0.0862
	Oblique	35.6660	3.2502	3.5655	0.2475	0.1990
	Horizontal	9.5921	0.8559	0.9095	0.0587	0.0601
I4	Vertical	15.7520	1.5280	1.4883	0.2239	0.1527
	Oblique	41.0790	3.7065	4.0714	0.2980	0.2354
	Horizontal	11.4200	1.0155	1.0912	0.0707	0.0720
I5	Vertical	7.9052	0.8754	0.9923	0.1043	0.0699
	Oblique	29.5210	2.6513	3.4492	0.2288	0.1847
	Horizontal	8.6408	0.7717	0.7896	0.0524	0.0535
I6	Vertical	7.4113	0.8270	1.0296	0.1061	0.0711
	Oblique	27.7746	2.5005	3.1845	0.2129	0.1715
	Horizontal	7.4957	0.6715	0.7087	0.0453	0.0465

N models = without implants; I models = with implants.

However, such an observation is restricted to stress considerations exclusively. Other factors, such as occlusal function and patient habits, should also be considered when designing RPDs.

Conclusions

Within the limitations of this study's design methodology, combined implant-and-tooth-supported mandibular Kennedy Class I RPDs may favorably alter stress concentrations in otherwise distal-extension support areas.

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