Strain Comparisons for Splinted and Nonsplinted Cement-Retained Implant Crowns

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The aim of this study was to compare strains generated by splinted and nonsplinted cement-retained implant crowns for two implants. A stereolithic resin cast was printed using computed tomography scan data from a patient. Two 4 × 6-mm implants were placed in the posterior left side of the cast. Splinted and nonsplinted cement-retained crowns were made. The three-dimensional image correlation technique was used for the measurement of strains as crowns were loaded up to 400 N in vertical and oblique directions with an Instron machine. Patterns and magnitudes of strain for splinted and nonsplinted crowns were similar. Results of this in vitro study suggest that splinting has a minimal effect on the load sharing of adjacent cement-retained crowns. *Int J Prosthodont 2013;26:235–238. doi: 10.11607/ijp.3254*

Splinting crowns on short implants has been shown to better distribute the occlusal loads between implants, minimize the transfer of horizontal load to the bone-implant interface, and increase the bone-surface area.[1] However, recent studies have also reported success with nonsplinted crowns on short implants.[2,3]

Previous experimental techniques used to evaluate load distribution have some disadvantages, such as limited qualitative data for photoelasticity and quantitative data limited to the location of gauges for the strain-gauge technique. The three-dimensional image correlation (3D DIC) technique was recently used for implant biomechanics and enables visual and quantitative analyses of strains of the entire surface of the models.[4,5] This study aimed to compare the strain distribution when splinted or nonsplinted crowns are cemented on adjacent short implants with internal conical connection using 3D DIC.

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Materials and Methods

Computed tomography data were used to print a stereolithic resin cast (Accudental) from a patient missing all mandibular molar teeth (Fig 1a). The elastic modulus of the resin (ABS transparent resin, DSM Somos) was 2,000 MPa, approximating published estimates for cancellous bone (1,507 MPa). Two 4 × 6-mm implants (Osseospeed, Astra Tech) were placed in the left side of the mandibular cast (Materialise Dental). Implants were coated with a thin layer of M-Bond 200 (Vishay). The impression of the mandibular cast was made with polyvinyl siloxane (Reprosil, Dentsply). Implant positions were transferred to a master cast using impression posts and implant analogs.

Splinted (n = 1) and nonsplinted (n = 1) cement-retained prostheses were fabricated on the master cast. TiDesign prefabricated engaging abutments (Astra Tech) were used. Type III gold (Midas, JF Jelenko) was used to fabricate the cement-retained prostheses. Splinted crowns ranged in height from 11 to 13 mm. Prostheses were cast, finished, polished, and tried on the stereolithic cast using the one-screw test to verify passivity (Figs 1b and 1c). Interproximal contacts were adjusted so that an 8-μm aluminum foil shim could be pulled between contacts without tearing. Prostheses were secured to the cast prior to testing using a torque driver set to 20 Ncm according to manufacturer recommendations.

Full-field strains were measured with the 3D DIC technique using commercial image correlation software (Vic-3D, version 2007) and a pair of high-resolution digital cameras (Point Grey Research). A synchronized stereo view of the casts was provided with this configuration during the experiment.

Fig 1a Stereolithic resin cast of the mandible.

Fig 1b Splinted cement-retained crowns.

Fig 1c Nonsplinted cement-retained crowns.

Fig 1d *(left)* Cast mounted for loading.

Fig 1e *(right)* Instron and dual camera setup.

A random dot pattern was applied to the external surface of the mandibular cast and prostheses. Cameras recorded changes in the random dot pattern using an array of 1,600 × 1,200 pixels as the casts were tested. In a stereovision arrangement, the calibration of each camera was achieved taking various images of the same target grid in different views.

A biaxial servohydraulic load frame was used to apply maximum static loads of 400 N in both vertical and 20-degree oblique directions to the anterior and posterior implant crowns using an Instron machine (model 1321) (Fig 1d). Three random vertical and oblique loading tests were performed on each of the prostheses (Fig 1e). An image correlation algorithm used the dot pattern to define correlation areas or virtual strain gauge boxes. Three-dimensional coordinates of these gauge box centers were determined for each recorded photograph and used to calculate strains throughout the entire surface of the casts. Strain distribution data were generated for both maximum (major) and minimal (minor) principal strains and compared using factorial analysis of variance (ANOVA) with a Tukey-Kramer post hoc test ($\alpha = .05$).

Results

Maximum and minimum principal strains around implants were analyzed. For this application, maximum principal strains were generally tensile (positive) whereas minimum principal strains were compressive (negative).

Maximum and minimal principal strain patterns were similar, and magnitudes were not statistically different for splinted and nonsplinted crowns under vertical and oblique loading (Figs 2 and 3, Table 1) ($P > .05$). However, the maximum and minimum principal strains under oblique loading were higher around the anterior implant for both splinted and nonsplinted restorations (Fig 4) ($P > .05$).

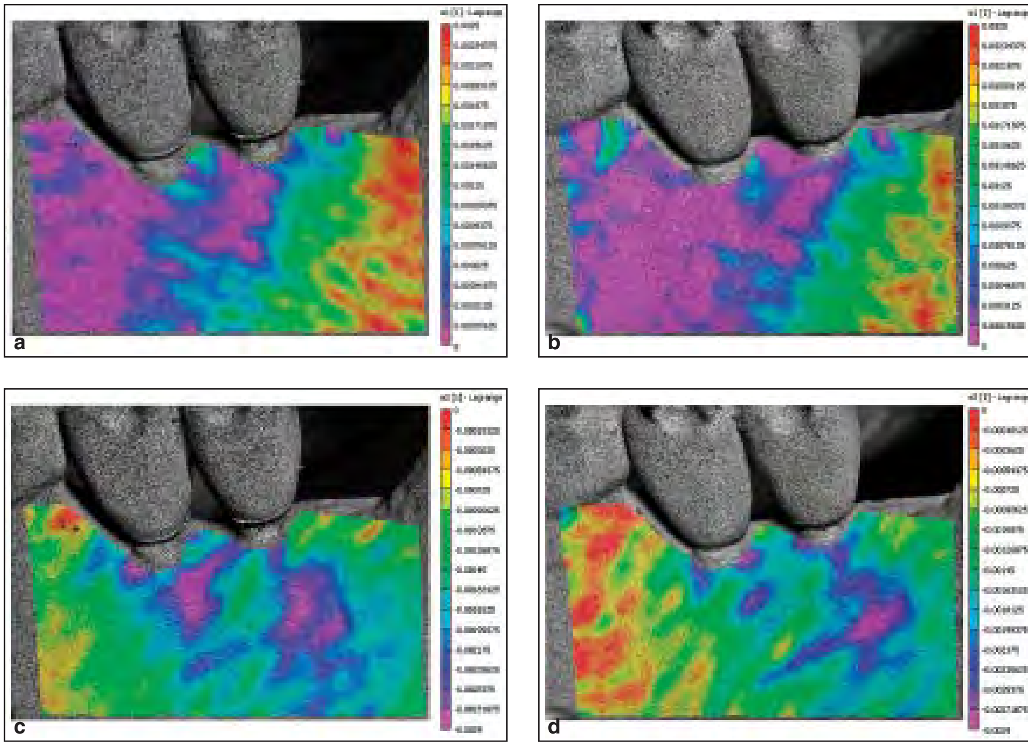

Fig 2a **Maximum** *principal strain for implants with splinted crowns loaded in a vertical direction.*

Fig 2b **Maximum** *principal strain for implants with nonsplinted crowns loaded in a vertical direction.*

Fig 2c **Minimum** *principal strain for implants with splinted crowns loaded in a vertical direction.*

Fig 2d **Minimum** *principal strain for implants with nonsplinted crowns loaded in a vertical direction.*

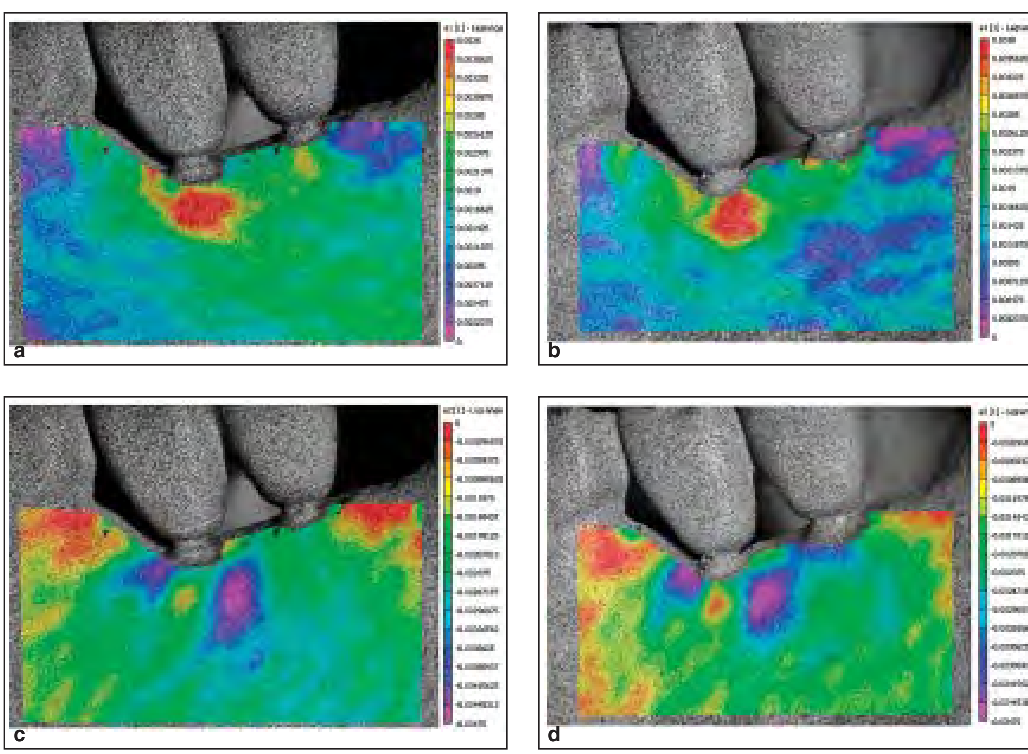

Fig 3a **Maximum** *principal strain for implants with splinted crowns loaded in an oblique direction.*

Fig 3b **Maximum** *principal strain for implants with nonsplinted crowns loaded in an oblique direction.*

Fig 3c **Minimum** *principal strain for implants with splinted crowns loaded in an oblique direction.*

Fig 3d **Minimum** *principal strain for implants with nonsplinted crowns loaded in an oblique direction.*

Discussion

In this in vitro study, maximum principal strains under vertical loading were seen mostly at the area where the mandible was fixated. However, minimum principal strains were concentrated around implants. Under oblique loading, both maximum and minimum principal strains were generated around the implants.

Table 1 Strains (Mean and SD) for Splinted and Nonsplinted Cement-Retained Restorations

Principal strain	Load direction	Prosthesis type	Mean	SD	*P*
Maximum					
Mean	0 deg	Nonsplinted	0.00087694	0.00015159	.92
		Splinted	0.00086754	3.3702E-05	
	20 deg	Nonsplinted	0.00133604	0.00012648	.59
		Splinted	0.00144318	0.0002919	
Peak	0 deg	Nonsplinted	0.00260214	0.00024762	.27
		Splinted	0.00288779	0.00029495	
	20 deg	Nonsplinted	0.00415984	7.7316E-05	.86
		Splint	0.0040335	0.00117236	
Minimum					
Mean	0 deg	Nonsplinted	−0.00127147	0.00015194	.47
		Splinted	−0.00139258	0.00022065	
	20 deg	Nonsplinted	−0.00157476	0.00032579	.43
		Splinted	−0.00180416	0.00030976	
Peak	0 deg	Nonsplinted	−0.004047477	0.001193591	.70
		Splinted	−0.003750167	0.000406175	
	20 deg	Nonsplinted	−0.004263707	0.000609828	.28
		Splinted	−0.004718257	0.00019162	

SD = standard deviation.

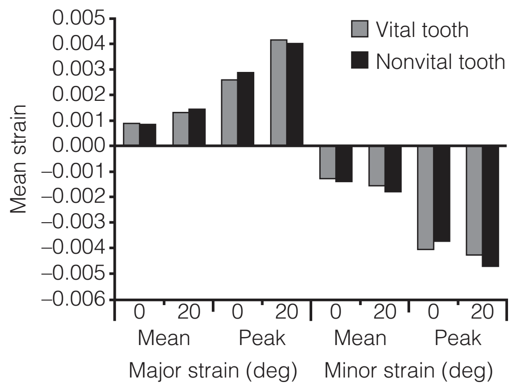

Fig 4 Mean and peak maximum (major) and minimum (minor) principal strains for nonsplinted and splinted cement-retained crowns.

Patterns and distribution of strains were similar for the splinted and nonsplinted cement-retained crowns for both vertical and oblique loading. However, strains were more evenly distributed between the two implants with vertical loading for both retention modes. For oblique loading, strain magnitudes were greater around the anterior implant compared with the posterior. It may be that this load angle caused displacement of the mandible and subsequent relief to the load on the posterior implant.

The present results agree with the clinical findings of Vigolo and Zaccaria[2] for cement-retained crowns. These authors suggested that multiple nonsplinted implants may be used in clinical situations. Clinical results supporting no splinting of consecutive cement-retained implant crowns were also reported by Bender.[3]

Conclusions

Although this in vitro study was limited in its ability to replicate osseointegration or clinical occlusal forces, the results suggest that splinting does not significantly affect strains distributed to bone when cement retention is used. Prospective clinical studies are needed to determine whether splinting cement-retained crowns affects the clinical outcome. Additionally, the results of the present study should not be applied to screw-retained restorations.

Acknowledgment

The authors reported no conflicts of interest related to this study.

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