Flexion characteristics of four-unit fixed partial denture frameworks using holographic interferometry

Gary R. Goldstein, DDS,[a] Anthony Wesson, DDS,[b]
Kenneth Schweitzer, DDS,[c] and Bradley Cutler, DDS[c]
Kriser Dental Center, Division of Restorative and Prosthodontic Sciences, New York University, New York, N.Y.

Flexion of a metal/ceramic fixed partial denture (FPD) framework under function can cause fracture of the porcelain or deterioration of the cement seal. This study evaluated the flexion under compressive load of a four-unit mandibular FPD replacing the second premolar and the first molar. Testing was accomplished with elapsed time holographic interferometry, using 39 porcelain fused-to-metal frameworks cast with a silver-palladium alloy. The results demonstrated that solder joints at the junction of the premolar and molar pontics flexed under a reduced compressive load and exhibited a higher failure rate than other connector designs. (J PROSTHET DENT 1992;67:609-13.)

The intraoral flexion of a metal/ceramic fixed partial denture (FPD) framework during function has serious consequences, because it can cause fracture of the porcelain[1] or disrupt the cement seal. Therefore a rigid framework must be achieved without compromising allied biologic and esthetic design parameters.

FPD frameworks may be cast in one-piece or as two or more solder-connected units. While investigators have discovered that three-unit FPD one-piece castings can be more accurate[2] or as accurate[3] as soldered individual units, many agree that the one-piece casting denies verification for the fit of individual retainers.[4] Since distortion increases as the casting length is extended,[5,6] it has been suggested that any framework exceeding three units should be cast in at least two pieces and then soldered.[7] Previous testing of the strength of soldered joints has been performed under tensile loading,[7-12] assuming there was a correlation with intraoral compressive loads. Anusavice et al.[13,14] believes that the flexural stress resulting from compressive loads was the principal type of stress transmitted to an intraoral prostheses.

In this investigation, deformation of a four-unit FPD metal/ceramic framework under compressive load could be

Presented in part at the Academy of Prosthodontics meeting, Palm Springs, Calif.
[a]Professor and Director of Prosthodontic Research, Division of Restorative and Prosthodontic Sciences.
[b]Former Assistant Professor.
[c]Clinical Assistant Professor.
10/1/35561

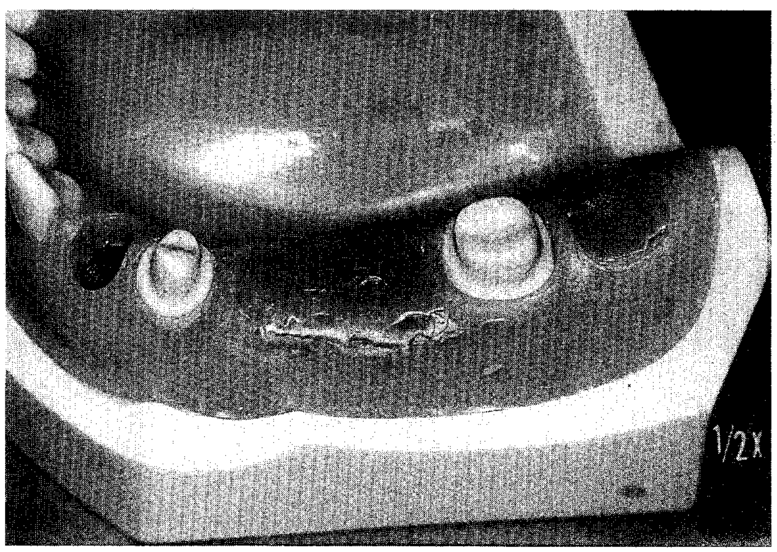

Fig. 1. Typodont with the teeth prepared.

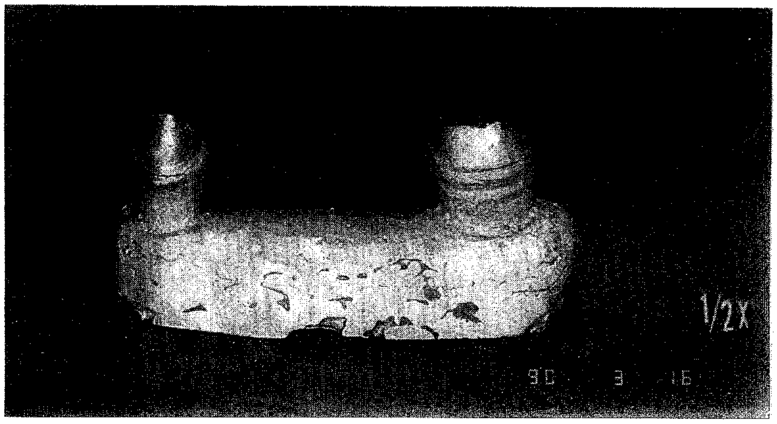

Fig. 2. Chromium-cobalt replica of the Typodont.

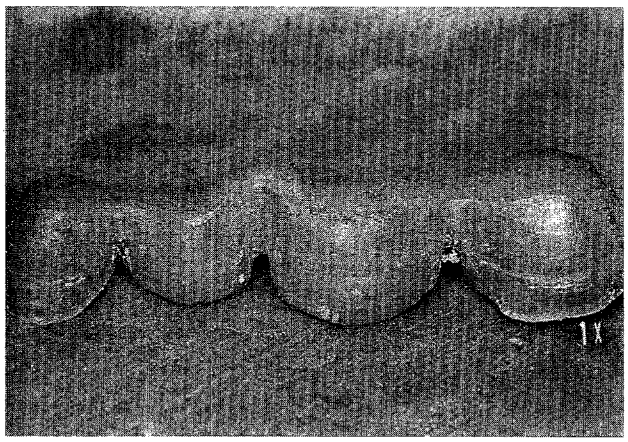

Fig. 3. Duralay pattern with margins corrected in wax.

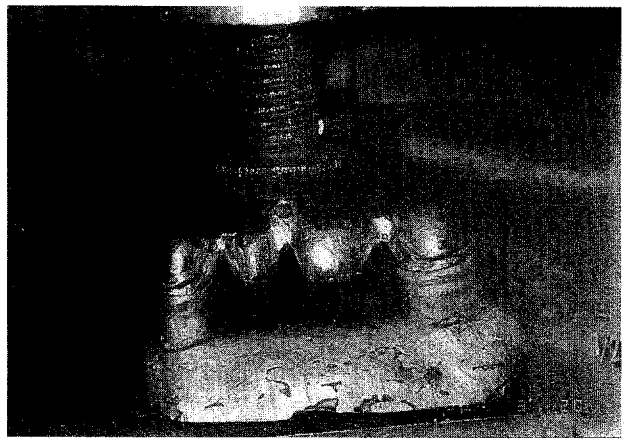

Fig. 5. Framework seated on alloy cast. Hydraulic press transmitted the load with a 9 mm steel ball held on the midspan loading platform by wax.

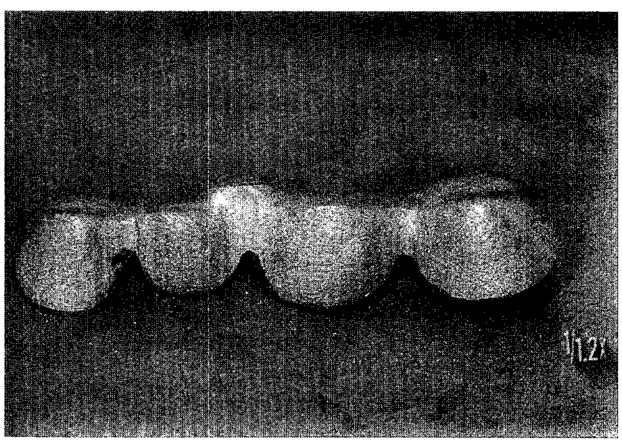

Fig. 4. Cast framework with midspan loading platform.

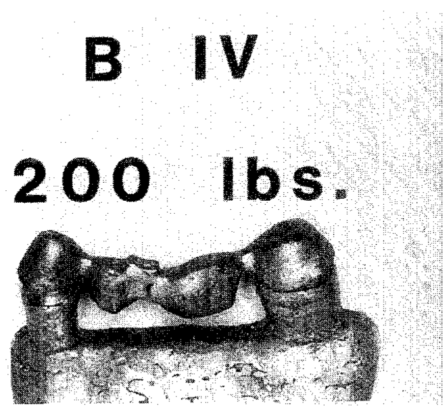

Fig. 6. A PP-MP solder-connected framework that failed at 200 lb.

detected by elapsed time holographic interferometry. This is an extremely sensitive instrument for identifying stress-induced distortions and nondistorted displacements in the tens of nanometers range.[15-18] In addition, this method also provided a permanent photographic record of the observed results.

MATERIALS AND METHODS

The first premolar and the second molar were prepared as abutments with a shoulder/bevel preparation (Fig. 1) on a Typodont (No. 662, Columbia Dentaform, New York, N.Y.) with the left second premolar and the first molar missing. The Typodont was duplicated in a chromium-co-

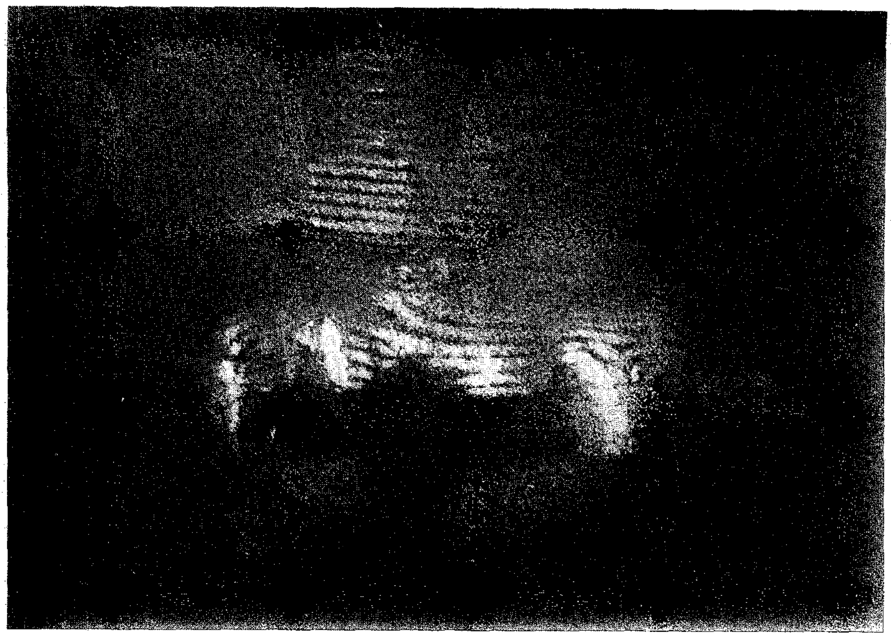

Fig. 7. Hologram of an MMP solder-connected framework. The fringes suggested that the PP was moving differently from the rest of the framework. Intricate fringes in the gingival half of the molar abutment indicated complex deformation.

balt alloy with a machine-milled horizontal base to ensure stability under load (Fig. 2).

One four-unit FPD framework was waxed, cast in a silver-palladium alloy (Jelstar, J. F. Jelenko Co., Armonk, N.Y.), fitted to the alloy cast, and used to fabricate a compound gypsum mold. Thirty-nine autopolymerizing Duralay (Reliance Dental Mfg. Co., Worth, Ill.) resinous patterns (Fig. 3) were prepared in the mold, corrected for marginal fit with wax on the alloy Typodont replica, and then cast in the silver-palladium alloy.

The 39 castings were subjected to the following:

1. Ten frameworks remained as one-piece castings (U).
2. Nine frameworks were sectioned and solder-connected midway between the molar pontic (MMP).
3. Ten frameworks were sectioned and solder-connected at the junction of the premolar pontic and the molar pontic (PP-MP).
4. Ten frameworks were sectioned and solder-connected at the junction of the premolar abutment and premolar pontic (PA-PP).

All frameworks were secured for fit on the alloy Typodont replica. The soldered units were sectioned with a 0.3 to 0.4 mm solder gap, indexed on the replica with Duralay, poured in soldering investment (Highspan, J. F. Jelenko Co.), and torch-soldered (Olympia Pre-Solder, J. F. Jelenko Co.). The midpoint of the span was designed as a shallow basin to allow for self-centering of the test load (Fig. 4). After recovery, the frameworks were heated to 1800° F and bench-cooled for four cycles to simulate porcelain application. The FPDs were sprayed with bronze paint to enhance their reflectivity.

A standard single-beam holographic system was constructed using sand damping and pneumatic isolation. The stage on which each prosthesis was tested consisted of a stainless steel support column and a platform. A hydraulic press was centered from above. Each prosthesis was tested under static occlusal loads applied at the midpontic depression with a 9 mm steel ball (Fig. 5). The applied loads were recorded directly from a hydraulic pressure gauge in pounds of force.

The prostheses were tested in numerical order but without any indication of their status, that is, soldered or unit cast. The results were then tabulated and each prosthesis was then identified as a soldered or unit cast.

Table I. Results

Group	Count	Mean	SD	Stat. sig. subsets
Unit-cast	10	207	33.44	*
MMP	9	167	57.40	*
PA-PP	10	162	64.81	*
PP-MP	10	112	39.33	*

Stat, Statistically; *sig*, significant; *SD*, standard deviation; *MMP, PA-PP, PP-MP*, see text for explanation.
*Significant at $p < 0.05$.

RESULTS

One hundred eighty-five holograms were performed. The results (Table I) illustrated nondestructive flexion on the unit-cast frameworks at an average of 207 lb. Midmolar pontic solder-connected frameworks (MMP) flexed at an average of 167 lb, and premolar pontic-to-the premolar abutment solder-connected frameworks (PP-PA) flexed at an average of 162 lb, while premolar pontic-to-molar

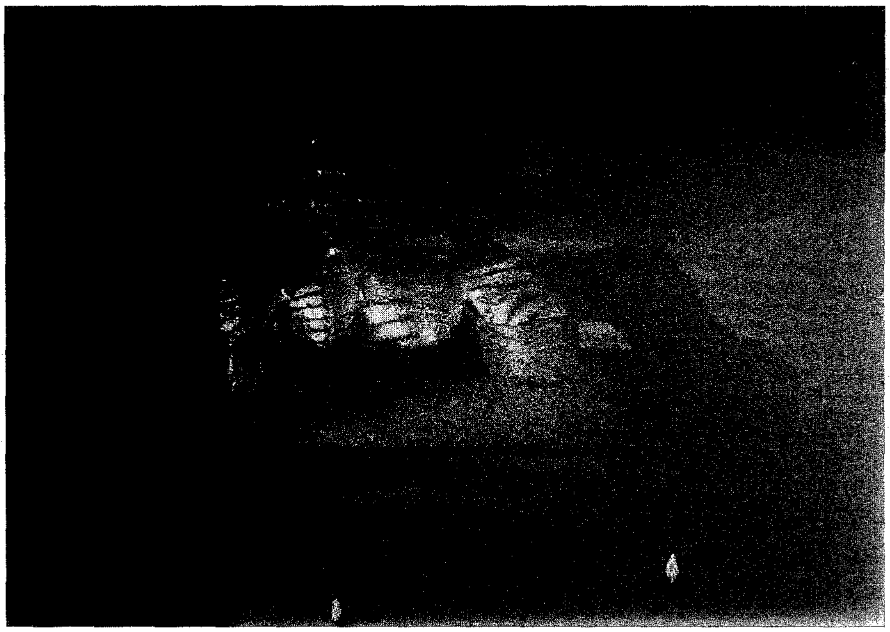

Fig. 8. Hologram of a PP-PA solder-connected framework. Uniform horizontal fringes indicated seating of the framework. Intricate fringes in gingival half of molar abutment indicated complex deformation.

Fig. 9. Hologram of PP-PA solder-connected framework as load was raised from 175 to 200 lb. Fringes on PP and PA were in different directions from fringes on MA and MP, indicating framework was deforming at the midspan. Intricate fringes in the gingival half of molar abutment indicated complex deformation.

solder-connected frameworks (PP-MP) flexed at an average of 112 lb. Ten of the frameworks failed under compressive loading (Fig. 6), while nine premolar pontic-to-molar pontic solder-connected frameworks (PP-MP) failed at an average of 194 lb, and a one-unit cast framework failed at 250 lb. Seven frameworks distorted at the gingival third of the molar abutment in the 100 to 150 lb range.

One-way analysis of variance (ANOVA) and least significant difference tests verified that the premolar pontic-to-molar pontic solder-connected frameworks (PP-MP) were statistically different from the other groups.

DISCUSSION

According to the law of beams, the weakest point is located at the center of the beam. The four-unit framework had minimal thickness in the area of greatest stress concentration, so it was not surprising that all the failures occurred at the center of the beam (Fig. 6). What was disconcerting was that the failures for the nine premolar pontic-to-molar pontic solder-connected frameworks (PP-MP) occurred at an average of 194 lb, which is within the range of occlusal forces of 90 to 200 lb reported for the first molar area.[19]

Fig. 7 is a photo of a hologram of an MMP solder-connected framework. The exposures were made as the load was elevated from 150 to 175 lb. The fringe patterns on the premolar abutment projected at a 45-degree angle, while the pontics and molar abutment were relatively horizontal, indicating that the premolar abutment was moving in a different direction from the remainder of the framework. The intricate fringe patterns in the gingival half of the molar abutment indicated a complex deformation at the margin of the casting.

Fig. 8 is a hologram of a PP-PA solder-connected framework at a load of 100 to 125 lb. There were uniform horizontal fringes except at the gingival half of the molar abutment, indicating complex deformation of the framework.

Fig. 9 is a hologram of a PP-PA solder-connected framework as the load was elevated from 175 to 200 lb. The premolar pontic and the premolar abutment exhibited fringes at a 45-degree angle, while the molar abutment and pontic fringes were almost horizontal, indicating that the two sections were moving in different directions. The intricate fringe patterns in the gingival half of the molar abutment that appeared in the 100 to 125 lb range again revealed complex deformation.

The molar marginal deformation in the seven frameworks indicated that there were great stresses on the sealing cement that may contribute to the cement deterioration commonly observed.

CONCLUSIONS

1. Evaluation of nondestructive flexion of four-unit FPD metal/ceramic frameworks by elapsed time holographic interferometry demonstrated that soldered joints at the premolar pontic and molar pontic flexed under a reduced compressive load and exhibited a greater failure rate than other connector designs.

2. Marginal distortion observed at the distal abutment of a mandibular four-unit FPD under compressive loading may cause cement deterioration.

3. Nondestructive testing using holographic interferometry has been confirmed as an efficient dental research approach and has potential for future investigations.

REFERENCES

1. McLean JW. Dental ceramics: Proceedings of the First International Symposium on Ceramics. Chicago: Quintessence Publishing Co, Inc, 1983:348.
2. Huling JS, Clark RE. Comparative distortion in three-unit fixed prostheses joined by laser welding, conventional soldering, or casting in one piece. J Dent Res 1977;56:128-34.
3. Fusayama T, Wakumoto S, Hosoda H. Accuracy of fixed partial dentures made by various soldering techniques and one-piece casting. J Prosthet Dent 1964;14:334-42.
4. Shillingburg HT Jr, Hobo S, Whitett LD. Fundamentals of fixed prosthodontics. 2nd ed. Chicago: Quintessence Publishing Co, Inc, 1981:403.
5. Bruce RW. Evaluation of multiple unit castings for fixed partial dentures. J Prosthet Dent 1964;14:939-43.
6. Bruce RW. Clinical applications of multiple unit castings for fixed prostheses. J Prosthet Dent 1967;18:359-64.
7. Stade EH, Reisbick MH, Preston JD. Preceramic and postceramic solder joints. J Prosthet Dent 1975;34:527-32.
8. Sloan RM, Reisbick MH, Preston JD. Postceramic soldering of various alloys. J Prosthet Dent 1982;48:686-9.
9. Preston JD, Reisbik MH. Laser fusion of selected dental casting alloys. J Dent Res 1975;54:232-8.
10. Staffanou RS, Radke RA, Jendresen MD. Strength properties of soldered joints from various ceramic metal combinations. J Prosthet Dent 1980;43:31-9.
11. Rasmussen EJ, Goodkind RJ, Gerberich WW. An investigation of tensile strength of dental solder joints. J Prosthet Dent 1979;41:418-23.
12. Lautenschlager EP, Marker BC, Moore BK, Wildes R. Strength mechanisms of dental solder joints. J Dent Res 1974;53:1361-7.
13. Anusavice KJ, Okabe T, Galloway SE, Morse PK. Flexure test evaluation of presoldered base metal alloys. J Prosthet Dent 1985;54:507-17.
14. Anusavice KJ, Shafagh I. Inert gas presoldering of nickel-chromium alloys. J Prosthet Dent 1986;55:317-23.
15. Young JM, Altschuler BF. Laser holography in dentistry. J Prosthet Dent 1977;38:216-24.
16. Schwaninger B, Schmidt RL, Hurst RVV. Holography in dentistry. J Am Dent Assoc 1977;95:814-7.
17. Burstone C, Pryputniewicz R, Bowley W. Incisor tooth displacement in the human. J Dent Res 1976;55(special issue B):104.
18. Wesson A, Goldstein GR, Schulman A. Flexion characteristics of fixed prosthodontic frameworks detected by elapsed-time holographic interferometry. J Prosthet Dent 1988;60:308-10.
19. Phillips RW. Science of dental materials. 9th ed. Philadelphia: WB Saunders Co, 1991:57.

Reprint requests to:
Dr. Gary Goldstein
Kriser Dental Center
Division of Restorative and Prosthodontic Sciences
345 East 24th Street
New York, NY 10010

CONTRIBUTING AUTHOR

Allan Schulman, DDS, MS, Professor and Associate Head, Division of Restorative and Prosthodontic Sciences (Dental Materials), Kriser Dental Center, New York University, New York, N.Y.