J. Dhaka National Med. Coll. Hos. 2022; 28 (02): 23-27

Original Article

A Comparative Study on Fatigue Resistance Between Cobalt-Chromium and Nickel-Chromium Occlusal Rest

Asheque Rahman[1], Marium Choudhury[2], Kazi Shagufa Yazdi[3], Mohammad Shamsuzzaman[4]

[1]Assistant Professor and Unit Head, Department of Prosthodontics, Delta Medical College, Dental Unit, [2]Associate professor and Head, Department of Periodontology and Oral Pathology, Bangladesh Dental College, [3]Associate professor, Department of Pedodontics and Dental Public Health, Bangladesh Dental College, [4]Associate professor and Head, Department of Science of Dental Materials, Bangladesh Dental College.

Abstract:

Background: Fatigue failure in a removable cast partial denture framework includes fracture of the occlusal rest at the rest-minor connector angle.

Objective: To evaluate the fatigue resistance of 0.7mm–thick occlusal rests casted with Cobalt-Chromium (Co-Cr) and Nickel-Chromium (Ni-Cr) alloy.

Materials and Method: It was a comparative observational in vitro study was carried out in the Department of Prosthodontics, Faculty of Dentistry, Bangabandhu Sheikh Mujib Medical University & Material & Metallurgy Department, Bangladesh University of Engineering & Technology (BUET). The study was carried out during the period of January 2006 to December 2007. Total 70 casted metals with no porosity, no cracks and metal thickness 0.7 mm were included. This divided into two groups, Group-A consisted of 35 occlusal rest casted with Ni-Cr alloy and Group-B consisted of 35 occlusal rest casted with Co-Cr alloy.

The specimen consisted of occlusal rest (0.7x2.0x10 mm), vertical minor connector (0.9x2.0x5.0 mm), and denture base connector (1.5x5.0x25 mm). Thirty-five specimens of each group were casted with Co-Cr and Ni-Cr alloy. Five specimens from each group were subjected to a load-deflection test conducted to determine the amount of deflection to be used in fatigue test. The fatigue test was performed such that the occlusal rest component was deflected by displacing the denture base component in a tissue ward direction. Predetermined denture base displacement values of 0.25 and 0.49 mm were applied for Co-Cr and Ni-Cr alloy specimens respectively, and repeated at a rate of 500 cycles/min by use of a displacement-controlled fatigue-testing machine, until occlusal rest failure occurred or a preset limit of 2 million cycles was achieved. The survival rates of the occlusal rests were calculated assuming a chewing cycle of $2x10^2$ per year. All data of the study were collected and recorded in specific parameters of fatigue resistance and survival rate of occlusal rest. Data were analyzed by using computer based programmed statistical package for social science (SPSS) for windows version 15. Student's t-test was done to find out the statistical significance. P-value <0.05 was considered as significant.

Results: The mean fatigue resistance of Co-Cr alloy was1559066 cycle, Ni-Cr alloy was 383300 cycles. The mean load deflection of Co-Cr alloy was 0.25mm; Ni-Cr alloy was 0.49mm.

Conclusions: Co-Cr occlusal rest is more rigid and resistant to fatigue than Ni-Cr occlusal rest.

Keywords: Fatigue resistance, Cobalt-Chromium, Nickel-Chromium, Occlusal rest.

Introduction

Usually mechanical failures in removable cast partial denture (RPD) frameworks do not occur immediately, but after years of service some failures have been reported.[1,2] These reports indicate that the components of the framework undergo fatigue, a mode of failure whereby a material or structure eventually fails after being subjected to repeated stresses. Studies have shown that normal mastication can produce thousands of stress cycles per day.[3] Thus fatigue resistance is an important factor in the clinical durability of dental materials.

Among cast RPD components, greater attention has been given to studies and experiments on fatigue behavior of clasp arms.[4-6] Ben-Ur et al.[7] studied the rigidity of major connectors when subjected to bending and torsion forces, whereas Ohkubo et al.[8] compared the fatigue strengths of different denture base designs for RPDs.

The occlusal rest is an integral part of cast RPD design. Its primary function is to provide vertical support for the denture. In doing so, it also serves to maintain stability of the denture, protects the underlying mucosa from impingement, and distributes occlusal loads to the abutment teeth. Kratochvil[9] has stated that the occlusal rests receive the greatest force produced in the mouth during function and that the first consideration for these rests is rigidity, so they will not flex under masticatory loads. A rest that is too thin will deform elastically, a greater proportion of the load will be transferred to the residual ridge, and the rest will fracture as a result of fatigue.[10]

Clinically, fatigue failures in cast RPD's include the breakage of the occlusal rest, which usually occurs at the angle formed by the minor connector and the rest as it crosses the marginal ridge of the abutment tooth.[7-9] Sometimes the fracture occurs sooner than could be expected after placement of the prosthesis.

The reasons often cited include the following: Thin metal alloy because of insufficient rest seat preparation, internal defects including porosity in the framework and accidental distortion.[7,9,11]

To provide the required rigidity and resistance to fracture, the occlusal rest should be 1.0 to 1.5 mm thick[7,12] and 2.0 to 2.5 mm wide where it crosses the marginal ridge of the abutment.[13] This is made possible when an adequate rest seat is prepared on the abutment tooth. In spite of this guideline, however, rest seats with depths less than 1.0 mm has been observed among general dentists, postgraduate students, and faculty Culwick et al.[14] To date, the longevity of the occlusal rests intraorally or the actual dimensions of rests that have failed clinically have not been reported.

Fatigue test is believed to simulate the clinical situation. Studies have shown that some materials and RPD designs possess greater fatigue resistance than others.[15,16] Thus, information on the fatigue behavior of materials and structures would guide dentists and dental technicians during RPD design, material selection, and fabrication.

Co-Cr and Ag-Pd-Cu-Au alloys are used to fabricate denture frameworks. Both are alternatives to the more expensive gold alloys. Co-Cr alloy as a standard alloy and Nickel-chromium alloy were used for in vitro studies and fabrication of cast RPD frameworks.

Co-Cr and Ag-Pd-Cu-Au alloys are used to fabricate denture frameworks. Both are alternatives to the more expensive gold alloys. Co-Cr alloy as a standard alloy and Nickel-chromium alloy were used for in vitro studies and fabrication of cast RPD frameworks.

Previously a study was done to evaluate the fatigue resistance of 0.8-mm–thick occlusal rests cast with Co-Cr and Ag-Pd-Cu-Au alloys.[17] This in vitro study was designed to evaluate the fatigue resistance of 0.7mm thick occlusal rests casted with Co-Cr alloys and Ni-Cr alloy.

Materials and methods

It was a comparative observational in vitro study was carried out in the Department of Prosthodontics, Faculty of Dentistry, Bangabandhu Sheikh Mujib Medical University & Material & Metallurgy Department, Bangladesh University of Engineering & Technology (BUET). The study was carried out during the period of January 2006 to December 2007. Total 70 casted metals with no porosity, no cracks and metal thickness 0.7 mm were included. This is divided into two groups; Group-A consisted of 35 occlusal rest casted with Ni-Cr alloy and Group-B consisted of 35 occlusal rest casted with Co-Cr alloy.

Study procedure: An experimental structure was designed with 3 components: occlusal rest, vertical minor connector, and denture base connector. The specimen consisted of occlusal rest (0.7 x 2.0 x 10 mm), vertical minor connector (0.9 x 2.0 x 5.0 mm), and denture base connector (1.5 x 5.0 x 25 mm). Although clinically the occlusal rest should be spoon-shaped and form an acute angle with the adjoining vertical minor connector. Data on the mechanical importance of these design principles were not found. Thus a simple design, which also facilitated the evaluation of cast specimens, was fabricated. The occlusal rest length was extended to 10 mm so that the specimen could be properly supported in the fatigue- testing machine. The 0.7-mm thickness was chosen.[17] A wax pattern of the master split mold of the model structure was made. After the wax elimination was completed at 800°C, fresh Co-Cr ingots were melted by use of Oxy acetelin flame and

filled into the molds by casting machine with centrifugal force. For Ni-Cr alloy, wax patterns were sprued and invested in a phosphate-bonded investment material (Investment: GC Corp). After the wax elimination was completed at 700°C, fresh Ni-Cr alloy ingots were melted by use of Oxy acetelin flame and filled into the molds by casting machine with centrifugal force. The specimens were devested after 1 hour of bench cooling, and residual investment material was removed. Polishing the specimens would closely resemble the clinical condition. Cantilever-type bending test was performed to determine the load and deflection to be applied to the fatigue test specimens. Five specimens from each group were randomly selected and tested using a universal testing machine. The denture base component was tightly gripped by a jig connected to a load cell. The occlusal rest component, held by 2 metal rollers, was deflected at a speed of 1 mm/min. The generated load (kgf) was recorded until the proportional limit of the tested alloy was reached. The flexural rigidity of the latter was estimated to be 8.07 times that of the former.[16,18]

Two factors were considered for the fatigue test: (1) the cyclical load/stress applied was within the proportional limit of the specimen; and (2) the maximum occlusal rest deflection/denture base displacement was within 0.5 mm, representing the reported resiliency of the residual ridge tissues.[19] Hence, on the basis of the results of the load-deflection test, a load of 1.3 kgf and its corresponding deflection values were selected: 0.25mm and 0.49mm for Co-Cr and Ni-Cr alloy specimens, respectively.

A motor-driven fatigue-testing machine (Fatigue testing machine-Terco) was used for this experiment. The machine had- (a) five 10-mm diameter rollers for holding the specimen; (b) a fixed loading frequency of 500 cycles/min; (c) a constant-displacement mechanism; and (d) a counter to record the number of fatigue cycles automatically. With a dial gauge, the denture base displacement value was set in the machine. The denture base component was held by the moving roller grips and the occlusal rest component was put on a fixed roller. The denture base was displaced cyclically effecting the pulsative sinusoidal deflection of the occlusal rest, until complete fracture was observed at the rest-vertical connector angle, or a preset limit of 2 million cycles was reached.

Data were collected on a predesign data collection sheet. All relevant data of the study were collected and recorded in specific parameters of Fatigue test and Survival rate analysis. Data were analyzed by using computer based programmed statistical package for social science (SPSS) for windows version 15. Student's t-test was done to find out the statistical significance. P-value <0.05 considered as significant.

Results

Table-I: Fatigue resistance in between the two groups (n=70).

Groups	N	Mean±SD (cycle)	P-value
Group A	35	383300±72291	0.001
Group B	35	1559066±610089	

Data were analyzed by using student 't' test

n- total number of specimen.

N-total number of specimen in each group.

Group A- Ni-Cr alloy.

Group B- Co-Cr alloy.

SD- Standard deviation.

Table-II: Mean Survival year in relation to survival cycle (n=70).

Groups	N	Mean±SD (year)	P-value
Group A	35	1.91±0.36	0.001
Group B	35	7.79±0.30	

Data were analyzed by using student 't' test

n- total number of specimen.

N-total number of specimen in each group.

Group A- Ni-Cr alloy.

Group B- Co-Cr alloy.

SD- Standard deviation.

Discussion

Fatigue fracture of the cast RPD framework occurs at specific sites that are determined by the design of the castings. Fracture usually occurs in areas where stress concentration is greater. With the occlusal rest, fatigue may occur at the angle where it joins the vertical minor connector, and fracture may be facilitated by inadequate alloy thickness and casting defects. This study was limited to the evaluation of fatigue resistance of an experimental 0.7-mm–thick occlusal rest, which was arbitrarily chosen to represent "inadequate rest seat depths" Culwick et al.[14] prepared by dentists. The 2-mm width represented the minimum recommended

dimension. A comparison with a 1-mm–thick occlusal rest was not made because adherence to textbooks' recommendations regarding occlusal rest dimensions would undoubtedly provide a more rigid and fatigue resistant structure. The occlusal rest length of 10 mm was designed so that the specimen would be properly supported in the fatigue-testing machine. Furthermore, an extended length was needed so that a wire, which was connected to the automatic stop-on-failure terminal button of the machine, could be attached to the occlusal rest component. A rigid occlusal rest is favorable since it should prevent the tissue-ward movement of the denture and eventual impingement of the underlying mucosa. In this regard, the fabrication of Co-Cr occlusal rest is more advantageous.

Kratochvil[9] and McGivney et al.[12] stated that to provide the required rigidity and resistance to fracture, the occlusal rest should be 1.0 to 1.5 mm thick; and 2.0 to 2.5 mm wide.[13] where it crosses the marginal ridge of the abutment. This is made possible when an adequate rest seat is prepared on the abutment tooth. In spite of this guideline, however, rest seats with depths less than 1.0 mm have been observed among general dentists, postgraduate students and faculty Culwick et al.[14] To date, the longevity of the occlusal rests intraorally or the actual dimensions of rests that have failed clinically have not been reported.

Different types of alloys are recommended for the construction of occlusal rest. Of them, we choose Co-Cr alloy as our study material because of its high properties corrosion resistance, high fracture toughness & ability to take high polish. A rigid occlusal rest is favorable since it should prevent the tissue-ward movement of the denture and eventual impingement of the underlying mucosa. In this regard, the fabrication of Co-Cr occlusal rest is more advantageous. This observation may be explained by the higher elastic modulus of this alloy. The higher the modulus of elasticity, the more rigid the material, resulting in its greater ability to resist deflection and distortion. Because the flexural rigidity of a bar is proportional to its modulus of elasticity and the cube of its thickness.[3,16] The use of Ag-Pd-Cu-Au occlusal rest necessitates a metal thickness of approximately 1.0 mm to provide the same rigidity as the 0.8- mm–thick Co-Cr occlusal rest. Thus, the choice to make thin rests may be compensated for by use of more rigid alloys.

In our study we have used Co-Cr alloy of 0.7 mm thickness for the construction of occlusal rest. The reduction of thickness in occlusal rest construction facilitated us in conserving more amount of dentine than 1 mm occlusal rest. Besides that it reduced the risk of tooth fracture, pulpal damage, and dentinal sensitivity as well as lessens the risk of developing secondary caries by saving more amount of dentine. Lot of researches has been done with the reduction of the thickness of occlusal rest. Culwick et al.[14] studied on occlusal rest made of Co-Cr alloy with 0.8 mm thickness. That study was limited to the evaluation of fatigue resistance of an experimental 0.8-mm–thick occlusal rest, which was arbitrarily chosen to represent "inadequate rest seat depths" prepared by dentists. The 2-mm width represented the minimum recommended dimension. A comparison with a 1-mm–thick occlusal rest was not made because adherence to textbooks' recommendations regarding occlusal rest dimensions would undoubtedly provide a more rigid and fatigue resistant structure. The use of a 0.8-mm–thick and 2.0-mm–wide occlusal rest may be adequate if fabricated with Co-Cr alloy.[13]

In our study we followed the similar method to see the fatigue resistance test of Co-Cr alloy. We have used the thickness of 0.7 mm instead of 0.8-1 mm to see the prognosis of the rest. In addition to that we have also used Ni-Cr alloy as the alternative alloy to construct occlusal rest. The above-mentioned author has used silver palladium alloy as the alternative to Co-Cr alloy. Our study has shown the higher load deflection and high efficacy to fatigue resistance cycle of Co-Cr alloy compared to Ni-Cr alloy. Even with the use of 0.7mm thickness of Co-Cr alloy in our study, the alloy was proved to be efficient and worthy.

Conclusion

Co-Cr occlusal rest is more rigid and resistant to fatigue than Ni-Cr occlusal rest. 0.7mm thick and 2.0mm wide occlusal rest casted with Co-Cr alloy are recommended to use for the fabrication of removable partial denture rather than 0.7mm thick and 2.0mm wide occlusal rest casted with Nickel-chromium alloy, but according to survival rate analysis the present limit of 2 million cycles represented 10 years of simulated clinical use, which was not satisfactory. Increased number and size of internal defects may increase the fatigue failure of cast occlusal rests. Further study with some other functional parameters with the same thickness of same metal.

Reference

1. Lewis AJ. Failure of removable partial denture castings during service. The Journal of Prosthetic Dentistry. 1978 Feb 1;39(2):147-9.

2. Vermeulen AH, Keltjens HM, Van't Hof MA, Kayser AF. Ten-year evaluation of removable partial dentures: survival rates based on retreatment, not wearing and replacement. The Journal of prosthetic dentistry. 1996 Sep 1;76(3):267-72.

3. Bates JF, Stafford GD, Harrison A. Masticatory function—a review of the literature: (II) Speed of movement of the mandible, rate of chewing and forces developed in chewing. Journal of Oral Rehabilitation. 1975 Oct;2(4):349-61.

4. Bridgemana JT, Marker VA, Hummel SK, Benson BW, Pace LL. Comparison of titanium and cobalt-chromium removable partial denture clasps. The Journal of prosthetic dentistry. 1997 Aug 1;78(2):187-93.

5. Matheson GR, Brudvik JS, Nicholls JI. Behavior of wrought wire clasps after repeated permanent deformation. The Journal of Prosthetic Dentistry. 1986 Feb 1;55(2):226-31.

6. Vallittu PK. Fatigue resistance and stress of wrought-steel wire clasps. Journal of Prosthodontics. 1996 Sep;5(3):186-92.

7. Ben-Ur Z, Matalon S, Aviv I, Cardash HS. Rigidity of major connectors when subjected to bending and torsion forces. The Journal of Prosthetic Dentistry. 1989 Nov 1;62(5):557-62.

8. Ohkubo C, Abe M, Miyata T, Obana JI. Comparative strengths of metal framework structures for removable partial dentures. The Journal of prosthetic dentistry. 1997 Sep 1;78(3):302-8.

9. Kratochvil FJ. Partial removable prosthodontics. Philadelphia: WB Saunders', 1988; 16-21.

10. Lammie G.A., Osborne, J. Partial dentures. 5th ed, Oxford: Blackwell Scientific Publications 1987;189-224.

11. Kazanoglu A, Smith EH. Replacement technique for a broken occlusal rest. Journal of Prosthetic Dentistry. 1982 Nov 1;48(5):621-3.

12. McGivney GP, Carr AB, McCracken WL. McCracken's removable partial prosthodontics', 10th ed, St. Louis: Mosby, 1999;77-91.

13. Jones RM, Goodacre CJ, Brown DT, Manoz CA, Rake PC. Dentin Exposure and Decay Incidence When Removable Partial Denture Rest Seats Are Prepared in Tooth Structure. International Journal of Prosthodontics. 1992 May 1;5(3).

14. Culwick PF, Howell PG, Faigenblum MJ. The size of occlusal rest seats prepared for removable partial dentures. British dental journal. 2000 Sep;189(6):318-22.

15. Cox J, Zarb G. Alternative prosthodontic superstructure designs. Swedish Dental journal. Supplement. 1985 Jan 1;28:71-5.

16. Stewart RB, Desjardins RP, Laney WR, Chao EY. Fatigue strength of cantilevered metal frameworks for tissue-integrated prostheses. The Journal of Prosthetic Dentistry. 1992 Jul 1;68(1):83-92.

17. Gapido CG, Kobayashi H, Miyakawa O, Kohno S. Fatigue resistance of cast occlusal rests using Co-Cr and Ag-Pd-Cu-Au alloys. The Journal of prosthetic dentistry. 2003 Sep 1;90(3):261-9.

18. Craig RG, Powers JM. Restorative dental materials, 11th ed, St. Louis:Mosby, 2001;68-91.

19. Monteith BD. Management of loading forces on mandibular distal-extension prostheses. Part I: Evaluation of concepts for design. The Journal of prosthetic dentistry. 1984 Nov 1;52(5):673-81.