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EVALUATION OF RETENTION OF TWO DIFFERENTLY CONSTRUCTED PARTIAL DENTURE FRAMEWORKS IN MANDIBULAR KENNEDY CLASS I

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ABSTRACT

Aim: To evaluate retention of Casted versus Milled Cobalt-chromium (Co-Cr) removable partial denture (RPD) framework in mandibular Kennedy class I.

Material & methods: A mandibular Kennedy class I educational model was scanned after distal rest seats preparation in first premolars bilaterally to produce standard tessellation language (STL) file. The latter was 3D-Printed to produce a 3D-printed resin cast. In the area of the second premolar bilaterally two implants were inserted, Multi-unit abutments were screwed to the implant, surveyed crowns were screwed to the abutments, and an STL file of the cast was obtained. Twelve Cobalt-Chromium (Co-Cr) RPD frameworks were then constructed and divided into two equal groups based on fabrication technique: casting (casted group) and milling (mill group). Evaluation of retention was done at different cycles starting from insertion (T0) to 4320 cycles (T4) simulating three years of function using a Universal testing machine.

Results: Mill group showed significantly higher initial (T0) retention compared to Casted group. Moreover, the highest loss of retention percentage (29%) was observed at the first interval (T0-T1) after simulating one month of function in Mill group. On the other hand, Casted group showed the highest loss of retention percentage (42%) at third interval (T2-T3) after simulating one year of function. After simulating three years of function, Mill group showed significantly higher retention values than Casted group.

Conclusion: Mill group showed significantly higher initial (T0) retention compared to Casted group. After simulating three years of function, Mill group showed significantly higher retention values than Casted group.

KEYWORDS: Mill, Cast, frameworks.

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INTRODUCTION

Removable partial dentures (RPD) remain a prevalent treatment option in comparison to more expensive ones [1]. Mandibular Kennedy class I possess several problems: absence of distal abutment, different types of support (teeth and soft tissue), and excessive torque on main abutments. Consequently, harmful effect on the abutment teeth and residual ridge resorption [2].

RPD frameworks are made from a variety of materials, including Co-Cr, Titanium alloys, PolyEther-Ether-Ketone and PolyEther-Ketone-Ketone. Owing to the remarkable mechanical, physical, biocompatible properties, tarnish and corrosion resistance of Co-Cr alloy, it can be recommended as a partial denture framework material [3-5].

Co-Cr RPD frameworks can be manufactured traditionally following the casting technique (Lost Wax Technique) or digitally following computer-aided design and computer-aided manufacturing (CAD/CAM) technology. Laboratory errors and casting shrinkage can affect Co-Cr RPD framework efficiency. The complex process of traditional RPD manufacturing technique involves the duplication of a cast, surveying to determine the optimal path of insertion, designing RPD components, investing, and casting. This requires a highly skilled dental laboratory professionals and a significant amount of time. Consequently, an inferior fit of the traditionally constructed partial denture framework can be anticipated [6-9].

Eventually, use of CAD-CAM technologies in construction of RPD frameworks significantly increased owing to the limitations of casting technique. RPD framework can be made digitally using two different methods: subtractive (Milling) or additive (3D-Printing) manufacturing techniques the two possible CAD/CAM manufacturing procedures [8, 10].

The Subtractive digital manufacturing technique uses a milling machine to construct the framework by removing bulk material from solid blocks by a Computer Numeric Controlled (CNC) machine [11].

Subtractive manufacturing may save time and reduces laboratory error, which may lead to a superior fit. However, milling of metal blocks may generate considerable waste and may require constant bur renewal. Accordingly, the cost of the framework increases [12].

Sufficient retention of RPD is required to resist the forces generated by functional muscle movements and food chewing. It poses a great challenge in free-end saddle cases. Improving retention enhances phonetics, chewing efficiency and esthetics. Hence, it promotes the patient satisfaction and quality of life [13, 14].

Reviewing previous research, a few studies compared retention of the Milled versus Cast RPD frameworks [8, 15]. Consequently, a question arises whether the construction technique might affect the retention of RPD frameworks in Kennedy class I cases. The null hypothesis was that there would be no significant difference regarding retention of Cast versus Milled Co-Cr RPD frameworks in Kennedy class I cases.

MATERIAL AND METHODS

Sample size:

The minimal sample size was calculated based on a previous study [16] using a power analysis software program (**GPower version 3.1.9.2**).

The sample size was calculated to detect the difference in retention among the studied groups, adopting a power of 80% (β=0.20) to detect a standardized effect size in the shear retention force (primary outcome) of 0.874, and level of significance 5% (α error accepted =0.05), the minimum required sample size was found to be six frameworks per group (number of groups=2) (Total sample size=12 frameworks). Any specimen loss from the study sample due to any reason was planned to be replaced to maintain the sample size.

Casted group: Six frameworks constructed by Casting technique.

Mill group: Six frameworks constructed by Milling technique

Model preparation:

A Kennedy class I partially edentulous educational cast was scanned by extraoral scanner (swing 3D scanner, DOF Inc., Korea) to obtain STL file. The cast was scanned after distal rest seats preparation in the first premolars bilaterally. The STL file of the stone cast was used to fabricate a 3D-printed resin cast (Model, Prophase Digital Solutions, Egypt). The STL file was imported into 3D-Printing software (Chitubox Pro, CDB-Tch, China). A Digital Light Processing (DLP) 3D-Printing machine (Microdont 1 pro 3D printer, Mogassam Co., Egypt) was employed to print resin cast.

Two parallel 3.5 mm diameter and 13 mm length implants (Neobiotic Co., Korea) were inserted in the second premolar region bilaterally. Afterwords, a torque wrench was used to tighten the implant fixture. The multi-unit abutments (Neobiotic Co., Korea) were then tightened to the fixture using multi-unit screwdriver. “Fig. 1”

Fig. (1) Multi-unit abutments tightened to the implant fixtures

The implants were scanned with scan body using an extra-oral scanner to obtain STL file. Using a computer program (Exocad software, Exocad GmbH, Germany) two surveyed crowns were designed to be screwed to the multi-unit abutments at the area of the second premolars bilaterally. The design of the crowns included prepared mesial occlusal rest seats, 2-3 mm guiding plane in the occlusal third of the distal surface and extend lingually just far enough and 0.5mm mesio-buccal undercut “Fig. 2”.

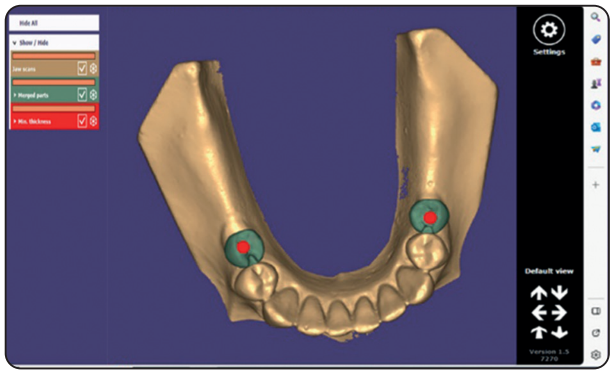

Fig. (2) Top view of the crowns with prepared mesial occlusal rests

The two STL file of the surveyed crowns were used to construct twenty-four Advanced Lithium Disilicate (CEREC TESSERA, DeguDent Gmbh, Germany). The crowns were constructed from Lithium Disilicate blocks with shade MT A2 using 5-Axis wet milling machine (CORiTEC® 350i Loader PRO, IMES-ICORE GMBH, Germany). The milled crowns were glazed with glazing paste (Universal overglaze, Dentsply Sirona, USA) in a compatible ceramic furnace (Vacumat 600M, VITA Zahnfabrik, Germany) at 760˚ for 2 min. Afterwards, they were screwed to the multi-unit abutments. The screw channels were hidden with shade A2 tooth colored composite resin (Filtek Z250 XT, 3M, United States) “Fig. 3”.

Framework designing:

The resin cast was scanned by an extra-oral scanner to obtain STL file. The STL file was

Fig. (3) Delivery of the finished crowns

imported to partial denture module of software (3Shape Removable Partial Design; 3Shape, Denmark) to design RPD frameworks. First, digital surveying was performed to determine the best path of insertion. Second, the RPD framework was designed to include meshwork denture base design with a 0.8 mm resin gap, lingual bar major connector and RPI clasp assemblies. The clasp assemblies were designed including an I-bar retentive arms that were properly designed to engage mesio-buccal undercut of 0.5mm depth on second premolars, proximal plates on the distal surfaces and reaching disto-lingual line angle of the abutments and mesial occlusal rests on the abutments. Two distal occlusal rests on the first premolars to act as indirect retainers. The junction between denture base and major connector act as external finish line. “Fig. 4”

Fig. (4) STL file of the RPD framework

Third, the RPD design included three horizontal accessory bars, two originating from distal ends of the saddle bilaterally and one originating from the midline of the lingual bar. The three bars intersected at a point representing the geometric center of the RPD framework [17] “Fig. 5”.

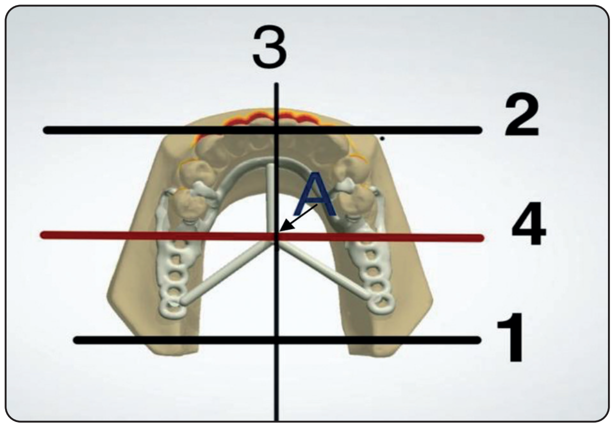

Fig. (5) The Geometric center

Moreover, a 17mm an equilateral Co-Cr triangle was 3D printed using Selective Laser Melting (SLM) 3D-Printer (VULCANTECH VM 120; GmbH, Hanover, Germany) to be soldered later to the geometric center of the frameworks to allow the hook of the universal testing machine (Instron Bluehill Lite; Instron Instruments Ltd., USA) to be attached to the frameworks at the geometric center.

Study groups:

Casted group frameworks:

The STL file of the framework design was imported to the CAM software to construct a 3D-printed resin framework following DLP technique with dental casting resin (Prophase Burn, prophase digital solution, Egypt). The 3D-Printed resin framework was tried on the cast. Once framework try-in was accepted, the construction of the other five resin frameworks was continued. The resin pattern was invested in a phosphate-bonded investment material (Xpand investment, Dentify,

Fig. (6) The finished framework constructed by Casting technique

Germany). The ceramic crucible of the casting machine (Fornax T, BEGO GmbH & Co.KG, Germany) was filled with the molten Co-Cr alloy (Magnum H50, MESA ITALIA S.R.L., Italy). The Co-Cr alloy solidus-liquidus temperature was 1334-1405˚C and its melting point was 1460˚C. Subsequently, the RPD framework was finished and polished from the outer surface. These procedures were repeated for the rest of RPD frameworks in this group. “Fig. 6”

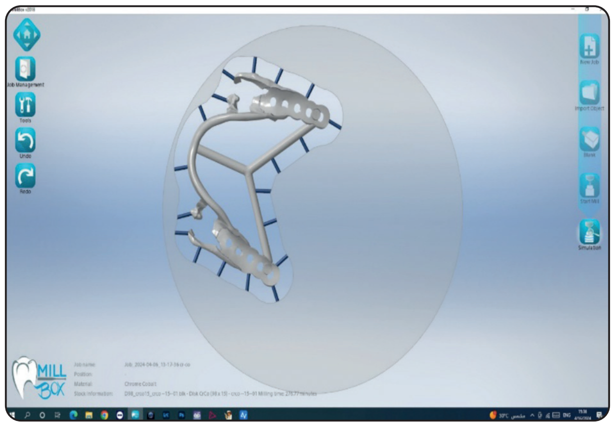

Fig. (7) Positioning the design on the blank

Mill group frameworks:

The STL file of the designed RPD framework was uploaded to dental CAM milling software (Mill BOX software, CIM system, Italy) which allowed positioning the framework design in the blank and adding supporting arms virtually “.Fig. 7”. Afterwords, the framework were milled using a 5-Axis milling machine (ED5X, EMAR MIILS. C2 Industrial complex, Egypt) from 15 mm Co-Cr blanks (Scheftner Dental Alloys, GmbH; Germany. At the end of the milling process, the framework was separated from the blank by cutting the supporting arms, then finished and polished from the outer surface following same technique as Casted group. “Fig. 8” These procedures were repeated for the rest of RPD frameworks in this group.

Fig. (8) The finished framework constructed by milling technique

Retention evaluation:

An iron cuboid block was constructed to secure the resin cast to the assemble of the Universal testing machine without any movement. The dimensions of the metal block were 8 cm length, 7 cm width and 2 cm height. The design of the metal block included three vertical arms (one anteriorly and two posteriorly). These arms were used to attach the cast to the block which in term was attached to the universal testing assembly with rectangular metal extension (20 mm length) from the base of the block. The hook was attached to the framework at the predetermined geometric center through the soldered 3D-Printed triangle "Fig. 9". A 5 kN tensile load with pull-out mode at a crosshead speed of 5 mm/min for each cycle of removal and the load required to dislodge the cast was measured in Newtons (N) and recorded after each cycle. The average of the 5 readings were used to determine the initial (0 month) retention force (T0). Previous process was repeated for T1, T2, T3 and T4 (120, 720, 1440 and 4320) insertion & removal test cycles. These cycles corresponded to one month, six months, one year, and three years simulation of function respectively.

Statistical analysis:

Data was collected, tabulated, and analyzed. Statistical analysis was performed with Statistical Package for the Social Sciences Statistics (SPSS for Windows, Version 23.0, IBM Corp., New York). Checking the distribution and normality of data was done using (Kolmogorov-Smirnov and Shapiro-Wilk tests). All data showed normal (parametric) distribution. Data were presented as mean and standard deviation (SD) values. Retention was measured in Newtons (N). Multiple comparisons Two-way ANOVA test was used to study the effect of fabrication technique, time and their interactions on retention. Tukey's post-hoc test was used for Pair-wise comparisons when test is significant. The results were considered significant, when P value was ≤ 0.05.

RESULTS

There was a statistically significant difference between both groups at all insertion and removal cycles from T0 (simulating insertion) and T4 (simulating three years) except at T1 (Simulating one-month).

At T0, T3, and T4 the retention of Mill group (11.45 ± 0.094 N, 5.28 ± 0.09 N and 3.97 ±0 .91 N respectively) was significantly higher than casted group (8.79 ± 0.094 N, 4.11 ± 0.09 N and 3.15±0.091 N respectively). On the other hand, at T2 the Casted group (7.13±0.091 N) had significantly higher retention compared to Mill group (6.63± 0.091 N).

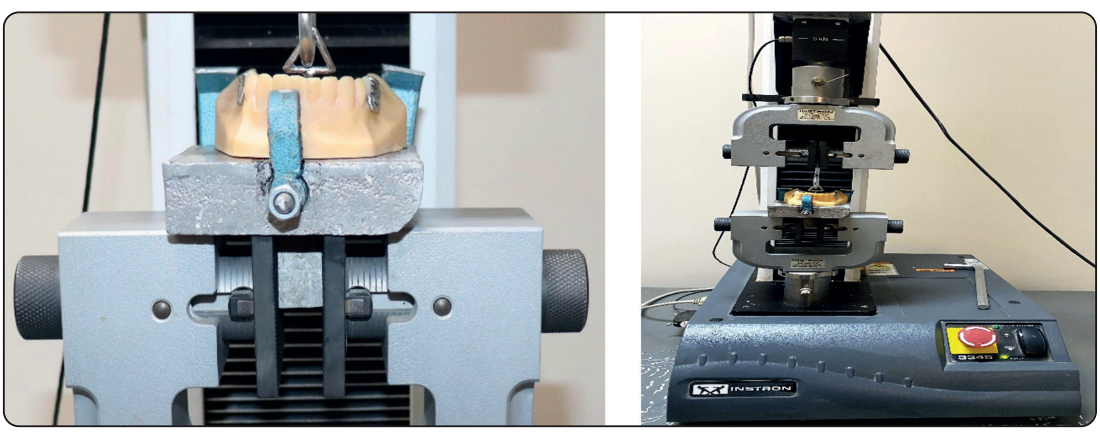

Fig. (9) Framework in the Universal Testing Machine

TABLE (1) The mean, Standard Deviation (SD) values and results for comparison between retention (N) of the Casted and Mill groups

Retention (N)					
Time	Fabrication technique				P-value
	Casted		Mill		
	Mean	SD	Mean	SD	
T0	8.79 ^{BC}	0.094	11.45 ^{AC}	0.094	<0.001*
T1	8.31 ^{AD}	0.091	8.16 ^{AD}	0.091	0.054
T2	7.13 ^{AE}	0.091	6.63 ^{BE}	0.091	<0.001*
T3	4.11 ^{BF}	0.09	5.28 ^{AF}	0.09	<0.001*
T4	3.15 ^{BG}	0.091	3.97 ^{AG}	0.091	<0.001*
P-value	<0.001*		<0.001*		

Significant at P ≤ 0.05

A and B superscripts in the same row indicate statisticallysignificant difference between techniques. C, D, E, F and G superscripts in the same column indicate statistically significant change by time

Regarding the Casted and Mill frameworks group, there was a statistically significant change in retention values by time. The post-hoc test revealed that there was a statistically significant decrease in retention values from T0 to T1, T1 to T2, T2 to T3 as well as T3 to T4.

Loss of retention percentage (%)

At all-time intervals, Loss of retention percentage (%) showed statistically significant difference between Casted and Mill groups. Moreover, the loss of retention percentage (%) at first, second and fourth intervals was significantly higher in Mill group (28.69±0.24%, 18.81±0.22% and 24.79±0.53% respectively) compared to Casted group (5.53±0.18%, 14.21±0.16% and 23.45±0.57% respectively). On the other hand, at third intervals the loss of retention percentage (%) in Casted group (42.33±0.54%) was significantly higher than Mill group (20.37±0.24%).

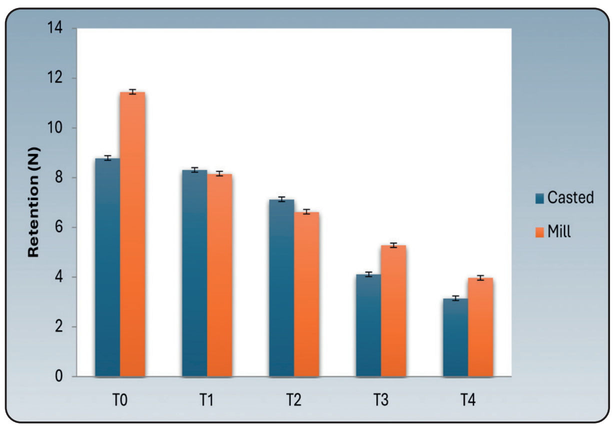

Fig. (10) Bar chart representing mean and standard deviation values for retention with different interactions of variables

Likewise, there was a statistically significant difference between loss of retention percentage at different times for both groups. Regarding the Mill group, pair-wise comparisons revealed that the significantly highest loss of retention percentage values was observed from T0 to T1. The statistically significantly lowest loss of retention percentage was observed from T1 to T2.

TABLE (2) The mean, standard deviation (SD) values and results of comparison between percentage loss of retention (%) with different interactions of variables

Time	Cast		Mill		P-value
	Mean	SD	Mean	SD	
1st interval (T0-T1)	5.53 BF	0.18	28.69 AC	0.24	<0.001*
2nd interval (T1-T2)	14.21 BE	0.16	18.81 AF	0.22	<0.001*
3rd interval (T2-T3)	42.33 AC	0.54	20.37 BE	0.24	<0.001*
4th interval (T3-T4)	23.45 BD	0.57	24.79 AD	0.53	<0.001*
***P*-value**	<0.001*		<0.001*		

****Significant at P ≤ 0.05,***

A and B superscripts in the same row indicate statistically significant difference between techniques, C, D, E and F superscripts in the same column indicate statistically significant difference between time

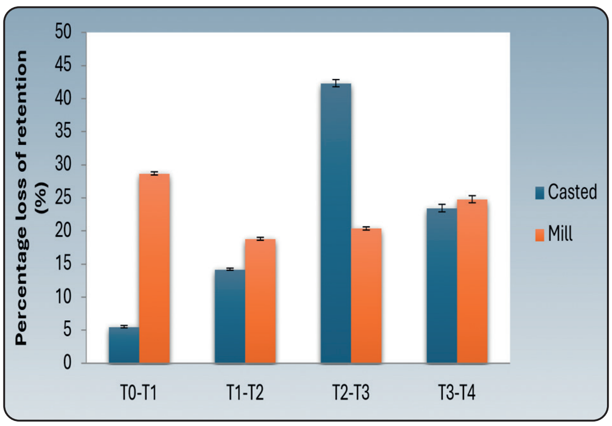

Fig. (11) Bar chart representing Mean and Standard Deviation values for percentage loss of retention with different interaction

Regarding Casted group, Pair-wise comparisons revealed that the statistically significantly highest loss of retention percentage values was observed from T2 to T3. T0 to T1 showed the statistically significantly lowest percentage loss of retention

DISCUSSION

Advancements in CAD/CAM technology of RPD frameworks fabrication result in improvement in efficiency, fewer laboratory steps required, fewer sources of error and fitness of the frameworks than traditional casting techniques [18]. The current study aimed to compare the retention values of RPD frameworks fabricated by Casting and Milling techniques.

Two implants placed in the second premolar region to receive multi-unit abutments with full surveyed crowns to ease retrievability of the crowns to be replaced with each framework avoiding the wear of the crowns that might affect retention values during the test. Kato et al noted macroscopically in his study wear marks on the areas where the clasp tip came in contact with the abutments and guiding lines [19].

The crowns within the study were milled using the same STL file to ensure reproducibility and standardization since 5-Axis milling machine offer high precision independent of type of ceramics, the area of the crown or the milling protocol [20].

CEREC TESSERA blocks which are modified Lithium disilicate were preferred than Zirconia in the second premolar as they give a more natural appearance during wide smile than Zirconia. Since CEREC TESSERA blocks included lithium disilicate crystals and platelet like Lithium alumino silicate crystals (Virgilite). During firing of the crowns, more virgilite crystals are formed. These crystals together might create high tensile strength and stop crack propagation. The manufacturer claims that this material is over 700 MPa strong in terms of biaxial flexural strength [21]. Amr et al compared fracture resistance of CEREC TESSERA with three other CAD/CAM Lithium Disilicate and had noted that CEREC TESSERA had the significantly highest fracture resistance [22]. Till now there are no studies available about using Lithium disilicate in conjunction with RPD.

The results of the present study showed that the Mill frameworks group initial retention was significantly higher ($p < 0.001$) when compared with Casted group. The superior results of the Mill frameworks could be attributed to the enhanced accuracy of construction technique using a 5-Axis milling machine leading to better engagement of the undercuts. Moreover, the high surface polish that resulted from the superior quality of surface finish achieved by milling [8].

Furthermore, the significantly lower initial retention of the Casted group might have resulted from increased number of laboratory steps which might led to greater errors. Residual thermal stresses develop because of rapid heating and cooling during Co-Cr framework manufacturing that could affect its physical and mechanical properties. As a result, it causes retentive tip displacement and inaccuracy of engagement the undercut. Also, the casting shrinkage for the metal alloys imply both the solidification shrinkage and the thermal contraction from solidification temperature to room temperature which may result in inaccuracies of the Cast RPD framework [23, 24].

The retention significantly decreases in both groups throughout time. This finding could be attributed to several factors; the retentive force decreases with the reduction in coefficient of friction of the clasps in relation to the abutment as well as with permanent deformation of clasps that might have occurred during retention tests. The change in clasp's coefficient of friction may dramatically decrease clasp's retentive force from the first to the second cycle [25].

The latter finding is in line with another study which compared the retention of Casted and SLM clasps. The study results showed decrease in retentive force owing to a larger gap between the clasp and the abutment results from fatigue deformation of clasps over cycles. Moreover, attrition of the internal surface of the clasp tip and the abutment dies may have led to further retention reduction. Wear induced fall in the friction coefficient, which resulted from surface roughness reduction [16].

Regarding the Mill group, from T0 to T1, the highest retention loss percentage occurred from the initial retention than Cast group, that could be explained by the higher accuracy of the milled frameworks compared to results in casted that led to intimate contact with the abutments crowns and greater engagement of the undercut may have occured. Consequently, rapid wear of the crowns might have occured and decrease in the coefficient of friction.

The current study results showed the lowest retention loss percentage of the Casted group was at the first two intervals (from insertion till six months post insertion simulation). This finding can be attributed to the higher elastic modulus of Cast Co-Cr alloy compared to Mill ones. This may have delayed the plastic deformation of clasps compared to Mill ones [26].

The null hypothesis in the current study was rejected since there was significant difference between fabrication technique (regardless of time), time (regardless of fabrication technique) and the interaction between variables regarding retention and loss of retention percentage outcomes.

CONCLUSION

Within the limitations of this in-vitro study, we can conclude that:

Mill group showed significantly higher initial (T0) retention compared to Casted group. After simulating three years of function, Mill group showed significantly higher retention values than Casted group.

Recommendations:

Further studies with large sample size are recommended. Moreover, clinical studies assess the behavior of differently constructed RPD frameworks in conjunction with CEREC TESSERA crowns.

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REFERENCES

1. Friel T. and S. Waia, Removable partial dentures for older adults. Primary dental journal, 2020. 9(3): p. 34-39.
2. Krol A.J., Clasp design for extension-base removable partial dentures. The Journal of Prosthetic Dentistry, 1973. 29(4): p. 408-415.
3. Zheng J., J.M. Aarts, S. Ma, J.N. Waddell, and J.J.E. Choi, Different undercut depths influence on fatigue behavior and retentive force of removable partial denture clasp materials: a systematic review. Journal of Prosthodontics, 2023. 32(2): p. 108-115.
4. Elhatery A., Retention and deformity of different RPD clasp materials (an invitro experimental study). Egyptian Dental Journal, 2023. 69(2): p. 1199-1208.
5. Grosgogeat B., A. Vaicelyte, R. Gauthier, C. Janssen, and M. Le Borgne, Toxicological risks of the cobalt–chromium alloys in dentistry: a systematic review. Materials, 2022. 15(17): p. 5801.
6. Rudd R.W. and K.D. Rudd, A review of 243 errors possible during the fabrication of a removable partial denture: part II. J Prosthet Dent, 2001. 86(3): p. 262-76.
7. Peng P.W., C.Y. Hsu, H.Y. Huang, J.C. Chao, and W.F. Lee, Trueness of removable partial denture frameworks additively manufactured with selective laser melting. J Prosthet Dent, 2022. 127(1): p. 122-127.
8. Heiba I.M., S. Mohamed Lotfy, F.N. Rizk, and M.E. Sabet, Effect of different digital technology on the adaptation and retention of Co-Cr partial denture frameworks. J Prosthodont, 2023.
9. Maalhagh-Fard A., N.J. Ostrander, T.R. Saunders, and T. Dadul, Comparison between selective laser melted and cast removable partial denture frameworks. The Journal of Prosthetic Dentistry, 2024.
10. Pereira A.L.C., A.K.B. de Medeiros, K. de Sousa Santos, É.O. de Almeida, G.A.S. Barbosa, and A.d.F.P. Carreiro, Accuracy of CAD-CAM systems for removable partial denture framework fabrication: A systematic review. The Journal of prosthetic dentistry, 2021. 125(2): p. 241-248.
11. Qiu J., W. Liu, D. Wu, F. Qiao, and L. Sui, Fit accuracy in the rest region of RPDs fabricated by digital technologies and conventional lost-wax casting: a systematic review and meta-analysis. BMC Oral Health, 2023. 23(1): p. 667.
12. Çelik G.E. and M.C. Balkaya, Metal Manufacturing Techniques Used in Prosthetic Dentistry. 2023.
13. Al Jaghsi A., F. Heinemann, R. Biffar, and T. Mundt, Immediate versus delayed loading of strategic mini-implants under existing removable partial dentures: patient satisfaction in a multi-center randomized clinical trial. Clinical oral investigations, 2021. 25: p. 255-264.
14. ELkerdawy M.W., S.N.A. Aboutar, and A.E.E. Fayyad, Kennedy Class II Problems and Treatment Options: A Review of Literature. Advanced Dental Journal, 2023. 5(3): p. 681-689.
15. Rizk F.N., M.E. Sabet, S.M. Lotfy, and I.M. Heiba, Application of different digital technology on partial denture frameworks. International Dental Journal, 2024. 74: p. S172-S173.
16. Zhang M., N. Gan, H. Qian, and T. Jiao, Retentive force and fitness accuracy of cobalt-chrome alloy clasps for removable partial denture fabricated with SLM technique. J Prosthodont Res, 2022. 66(3): p. 459-465.
17. Maryod W.H. and E.R. Taha, Retention of removable partial denture fabricated by digital designing and 3D printing technology-a cross over study. Advances in Dentistry & Oral Health, 2019. 10: p. 101-106.
18. Ahmed N., M.S. Abbasi, S. Haider, N. Ahmed, S.R. Habib, S. Altamash, M.S. Zafar, and M.K. Alam, Fit Accuracy

of Removable Partial Denture Frameworks Fabricated with CAD/CAM, Rapid Prototyping, and Conventional Techniques: A Systematic Review. Biomed Res Int, 2021. 2021(1): p. 3194433.

19. Kato Y., A. Tasaka, M. Kato, J. Wadachi, S. Takemoto, and S. Yamashita, Effects of repetitive insertion/removal cycles and simulated occlusal loads on retention of denture retainers. Dental Materials Journal, 2021. 40(5): p. 1277-1283.

20. Al Hamad K.Q., R.B. Al-Rashdan, B.A. Al-Rashdan, and N.Z. Baba, Effect of Milling Protocols on Trueness and Precision of Ceramic Crowns. J Prosthodont, 2021. 30(2): p. 171-176.

21. DJ F., CEREC Tessera Restorative Whitepaper. 2021.

22. Mohammad M., Fracture Resistance Of Four Different Types Of Cad/Cam Lithium Disilicate Endocrowns. Egyptian Dental Journal, 2023. 69(2): p. 1493-1500.

23. Dunham D., J.S. Brudvik, W.J. Morris, K.D. Plummer, and S.M. Cameron, A clinical investigation of the fit of removable partial dental prosthesis clasp assemblies. J Prosthet Dent, 2006. 95(4): p. 323-6.

24. Porojan S., M. Bîrdeanu, C. Savencu, and L. Porojan. Structural and morphological approach of Co-Cr dental alloys processed by alternative manufacturing technologies. in Journal of Physics: Conference Series. 2017. Year. 885(1): p. 012005.

25. Cheng H., M. Xu, H. Zhang, W. Wu, M. Zheng, and X. Li, Cyclic fatigue properties of cobalt-chromium alloy clasps for partial removable dental prostheses. J Prosthet Dent, 2010. 104(6): p. 389-96.

26. Erfan A.M., I.A. Radi, and N. Abd El Nabi, Retention Of Cast Chrome-Cobalt Versus Milled Chrome-Cobalt Telescopic Retainer For An Implant Supported Overdenture: An In Vitro Study. Advanced Dental Journal, 2024. 6(3): p. 522-530.