RETENTIVE FORCES OF POLYARYLETHERKETONE REMOVABLE PARTIAL DENTURE CLASP ASSEMBLIES AND COBALT-CHROMIUM (CO-CR): A COMPARATIVE STUDY

by

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ABSTRACT

RETENTIVE FORCES OF POLYARYLETHERKETONE REMOVABLE PARTIAL DENTURE CLASP ASSEMBLIES AND COBALT-CHROMIUM (CO-CR): A COMPARATIVE STUDY

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Introduction: Traditional methods and materials for fabrication of removable partial dentures (RPDs) have been shown to be time consuming and error prone. With the recent trend for patients to request metal-free restorations, technological and material innovations have allowed for a potential transition from traditional materials and fabrication methods to computer-aided design and computer-aided manufacturing (CAD-CAM) techniques. Subtractive manufacturing of polymer-based materials may prove to be a more accurate and efficient solution for fabrication of RPD frameworks. **Purpose:** To compare retentive forces of traditionally fabricated cobalt-chromium (Co-Cr) RPD clasps with CAD-CAM fabricated RPD clasps of two contemporary thermoplastic polymers. **Materials and Methods:** On molar metal abutment teeth, 48 clasps were fabricated, including 16 Co-Cr clasps, 16 polyetheretherketone (PEEK) and 16 polyetherketoneketone (PEKK) thermoplastic polymer clasps. Individual clasps were inserted and removed on abutments utilizing a chewing simulator over 15,000 cycles to simulate over 10 years of insertion and removal. Retentive forces were measured utilizing a mechanical load tester at baseline and intervals of 1500 cycles. Data were analyzed with one-way Analysis of Variance, Tukey post-hoc, and paired T tests. **Results:** Mean retentive forces between all groups were significantly different ($P < 0.001$). Retentive forces of Co-Cr clasps were significantly higher than both polymers ($P < 0.001$). Mean baseline retentive forces were significantly different compared to final for Co-Cr and PEKK ($P < 0.001$, $P = 0.01$ respectively). An increase in retentive forces was observed for all clasps after the first period of cycling followed by a continual decrease for the remaining cycles. **Conclusions:** Thermoplastic polymer clasps demonstrated lower retentive forces compared to Co-Cr clasps, however, their retentive forces were relatively constant throughout the 15,000 cycles. This resistance to fatigue and ability to be fabricated with CAD-CAM technologies provides support for their clinical use.

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Chapter I: Introduction

Partial edentulism has been estimated to be greater than 20% in some areas of the United States. (Cooper, 2009). Consequently, the ability to treatment plan the partially dentate patient remains a common clinical task. Treatment options, including dental implants and fixed dental prosthesis (FPD) are generally preferred treatment options, however, cost of treatment and the patient's systemic health can necessitate alternative treatment options. If a traditional FPD or implant treatment is contraindicated, it has been stated that a clasp-retained removable partial denture (RPD) is a valid treatment alternative (Wostmann et al., 2005). Therefore, there continues to be a need for advances in RPD framework materials and fabrication techniques that allow for frameworks that are well-adapted, biocompatible, and mechanically sound.

Computer-aided design and computer-aided manufacturing (CAD-CAM) technologies have been accepted in the fabrication of numerous prostheses, from individual restorations to full-arch prostheses. (Arnold et al., 2018; Lee et al., 2017). With advances in CAD-CAM technologies, there have been advances in the materials that can best be designed and fabricated with digital techniques.

Metal-based RPD frameworks have been the standard for many years due their ability to be fabricated in thin cross-sections with desirable mechanical properties, however, esthetics, comfort, hypersensitivities, and potential biofilm production are some notable disadvantages. (Campbell et al, 2017; Benso et al, 2013). This has led to the development of metal-free framework materials including high performance polymers (HPPs) as alternatives. (Wiesli and Ozcan, 2015).

Polyaryletherketones (PAEKs) are high performance thermoplastic resins which differ among members of the PAEK family based on their ratio of keto- and ether- groups. (Fuhrmann et al., 2014). Currently, polyetheretherketone (PEEK) and polyetherketoneketone (PEKK) are the main PAEK family members utilized in dentistry. Recently, these materials have been used as frameworks for fixed and removable dental prostheses as well as implant abutments (Campbell et al, 2017; Dawson et al., 2018; Zoidis et al, 2016).

High performance polymers in the PAEK family may give the ability to incorporate design elements such as rests and direct and indirect retention with the possibility of increased biocompatibility and mechanical properties (Harb et al, 2019; Zoidis et al, 2016). Additionally, some purported advantages of HPPs include: production efficiency, higher elasticity, lightweight, lower material waste and improved esthetics (Campbell et al, 2017; Hu et al, 2019). These factors may allow for increased patient comfort and ultimately compliance.

A previous study by Tannous and colleagues evaluated retentive force values of thermoplastic resin clasp assemblies (Tannous et al., 2012). They found thermoplastic resin clasps to have lower retentive force values than cobalt-chromium alloy (CoCr) clasps but considered them to be acceptable for clinical applications. In their study, they fabricated the polymer clasp assemblies utilizing the conventional lost wax technique. A recent study that evaluated the fit of RPD clasps fabricated via CAD-CAM technologies compared to conventional lost-wax technique demonstrated significantly better fit of clasps fabricated by subtractive milling compared to the lost-wax technique (Arnold, et al., 2018)

Therefore, this in vitro study investigated the retentive force of thermoplastic resin clasp assemblies fabricated via CAD-CAM technologies with direct subtractive milling of the clasp compared to conventionally cast CoCr clasp assemblies over a simulated ten years of insertion and removal. The null hypothesis was that no difference would be detected between thermoplastic resin clasps and CoCr clasps.

Chapter II: Materials and Methods

Abutment Fabrication

A master abutment tooth model was fabricated using a mandibular first molar artificial tooth (Columbia Dentoform). The unprepared artificial tooth was embedded in autopolymerizing pattern resin (GC America). The artificial tooth was surveyed and contours modified to provide an undercut of 0.25mm on the distal buccal surface. An occlusal rest measuring 2.5mm in length, 3.0mm in width, and 2.0mm in depth was prepared on the mesial occlusal surface. Guide planes were created on the mesial and lingual surfaces with a milling unit (Paraskip M, Bego). The master abutment model was optically scanned (D2000 scanner; 3Shape) to obtain a standard tessellation language (STL) file format. The master abutment STL file was transferred to a 5-axis milling machine (CORiTec 650i, Imes-Icore GmbH) and 48 abutment teeth were milled directly from cobalt-chromium (Co-Cr) discs. After milling, the abutment teeth were separated from the discs and finished and polished with polishing burs and compound.

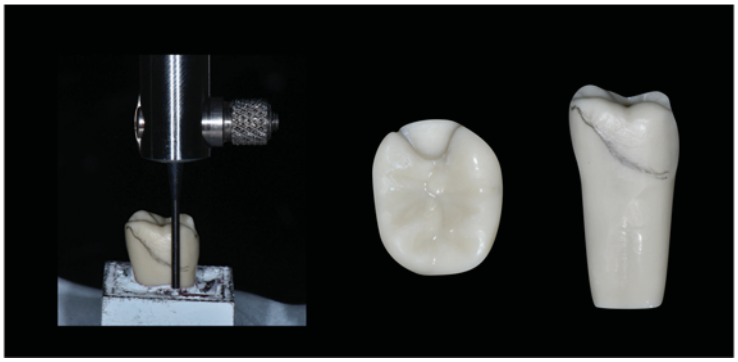

Fig. 1 – Surveying and preparation of artificial abutment tooth.

Polymer Clasp Assembly Design

The master abutment STL file was then imported into CAD software (Dental System, 3Shape) to begin designing the clasp assemblies. Digital surveying was completed and a path of insertion and survey line created. The desired undercut of 0.25mm was digitally achieved and all undercut areas were automatically blocked out by the software. The block out wax was then digitally removed where retentive elements were to be placed. The polymer-RPD clasp assemblies were then designed according to the manufacturers design parameters to include a rest, clasp assembly with retentive and reciprocating arms, and a guide plates. After the clasp assembly was digitally designed, a cylindrical attachment was positioned above the rest and parallel to the guide planes to be used in fixating the clasp assembly to the chewing simulator (Mechatronik Chewing Simulator, SD Mechatronik GMBH) and mechanical load testing machine (MTS Insight, MTS Systems). The completed polymer master design was then exported in standard tessellation language (STL) file format.

CoCr Clasp Assembly Design

Cobalt–chromium (CoCr) alloy clasp assemblies were designed in the same fashion as the polymer clasp assemblies. The same master abutment STL file was used. The design parameters used for the CoCr clasps were (1 mm × 1.2 mm retentive tip) including a rest, retentive and reciprocating arms, and a guide plates. The completed CoCr master design was then exported in STL file format.

Clasp Assembly Fabrication

The master design STL files for the polymer clasp assemblies and CoCr clasp assembly was transferred to a 5-axis milling machine (Wieland Zenotec Select Hybid, Ivoclar Vivadent). The milling strategy was defined according to the manufacturer's instructions. For the polymer clasp assemblies, 16 were milled directly from PEEK discs (Ultaire AKP, Dentivera Milling Disc, Solvay Dental) and 16 from PEKK discs (PEKKTON Ivory, Cendres Metaux). For the CoCr clasp assemblies, 16 patterns were milled directly from polymethyl methacrylate (PMMA) discs (Poly Cast, Harvest Dental). After the clasp assemblies were milled they were separated from the discs and milling sprues removed. The PMMA patterns were then sprued, invested (Wirovest, Bego), and cast in cobalt-chromium alloy (Wironium, Bego). Necessary finishing was completed and clasp assemblies were seated on individual abutments and full seating and adaptation verified visually.

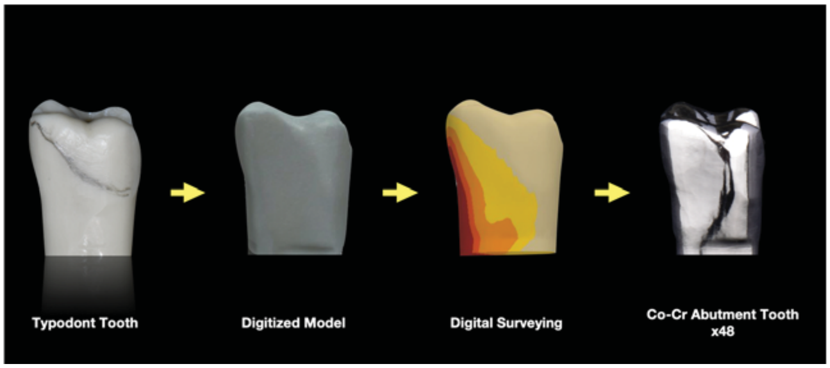

Fig. 2 - Workflow of abutment tooth fabrication.

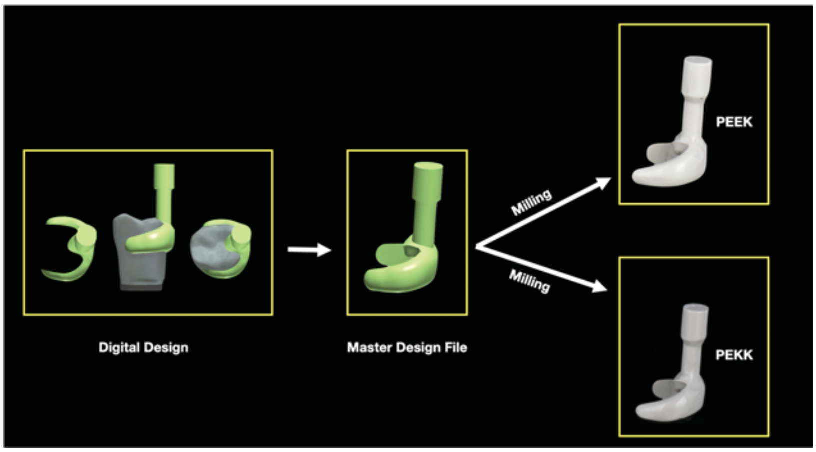

Fig 3 - Workflow of polymer clasp fabrication.

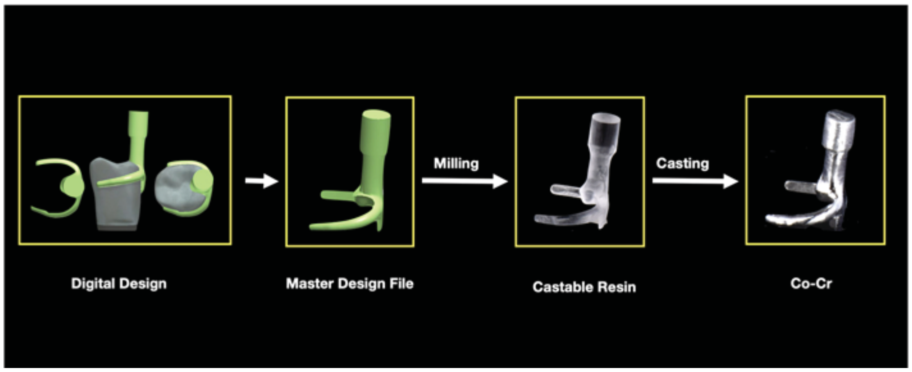

Fig. 4 – Workflow of CoCr clasp fabrication.

Fig. 5 – Completed setups of clasp assemblies on abutment teeth.

Testing

Abutment teeth were mounted in the lower compartment of a masticatory simulator (Mechatronik Chewing Simulator, SD Mechatronik GMBH). Individual clasp assemblies were than positioned on abutment teeth to full seating. The cylindrical attachment previously described was then utilized to fixate the clasp assemblies to the upper member of the masticatory simulator utilizing autopolymerizing pattern resin (GC America). The masticatory simulator allows for vertical movement of the clasp assembly to simulate insertion and removal of an RPD. Intervals of 1,500 cycles was utilized for a total of 15,000 cycles simulating 10 years of use. The test was performed at a constant speed of 8 mm/s. Every 1,500 cycles, the test assemblies were removed from the chewing simulator and positioned in a mechanical load tester (MTS Insight, MTS Systems). The force required to remove each clasp assembly from its abutment tooth was recorded. This was done until 15,000 cycles for each clasp assembly was completed. Statistical analysis was completed using a one-way analysis of variance (ANOVA) with Tukey post-hoc analysis. The significance level was set at 5% (= 0.05).

Fig. 6 – Mechanical load testing of clasp assembly.

Chapter III: Results

Figures 7, 8, 9, and 10 show the mean retentive force values required to remove clasp assemblies from their abutment teeth over 15,000 insertion and removal cycles. One-way ANOVA analysis showed the mean retentive forces between each material was significantly different (*p* <0.001). In this study, CoCr clasp assemblies displayed significantly higher retentive forces than both thermoplastic polymers PEKK and PEEK (*p* <0.001). The mean retentive force values for PEEK were significantly greater than for PEKK (*p* = 0.001). All clasps displayed an initial increase in retentive forces during the first cycling period followed by an overall continual decrease through the remainder of the 15,000 cycles.

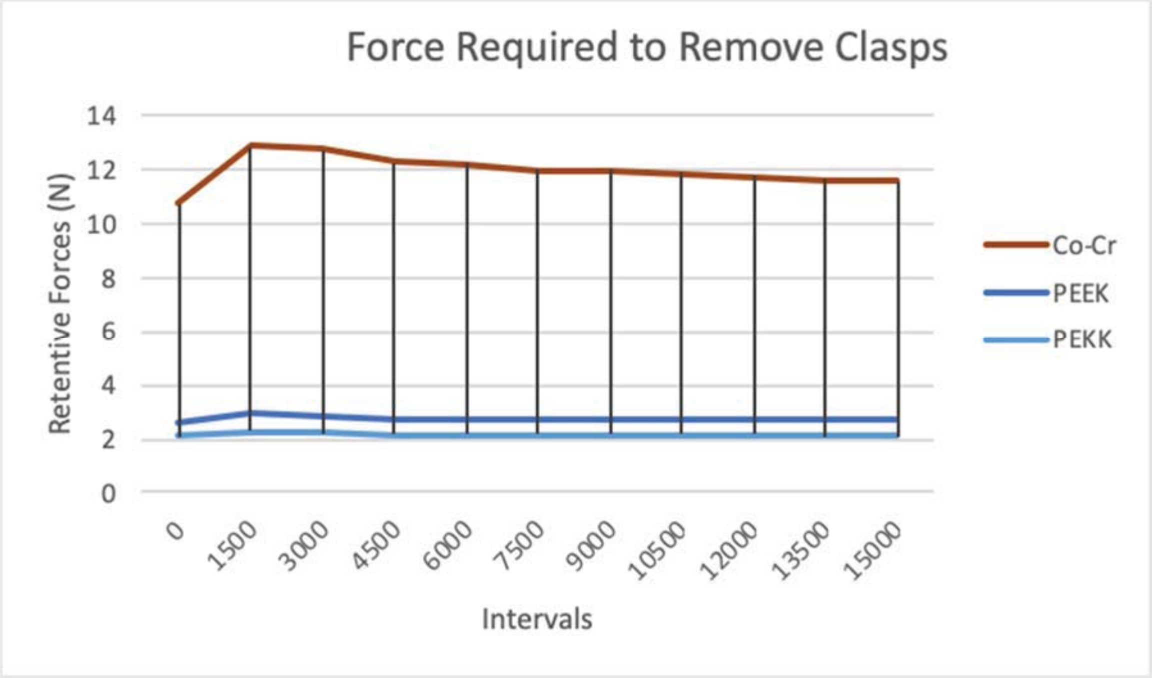

Fig. 7 – Mean force required to remove all clasps over 15,000 insertion and removal cycles.

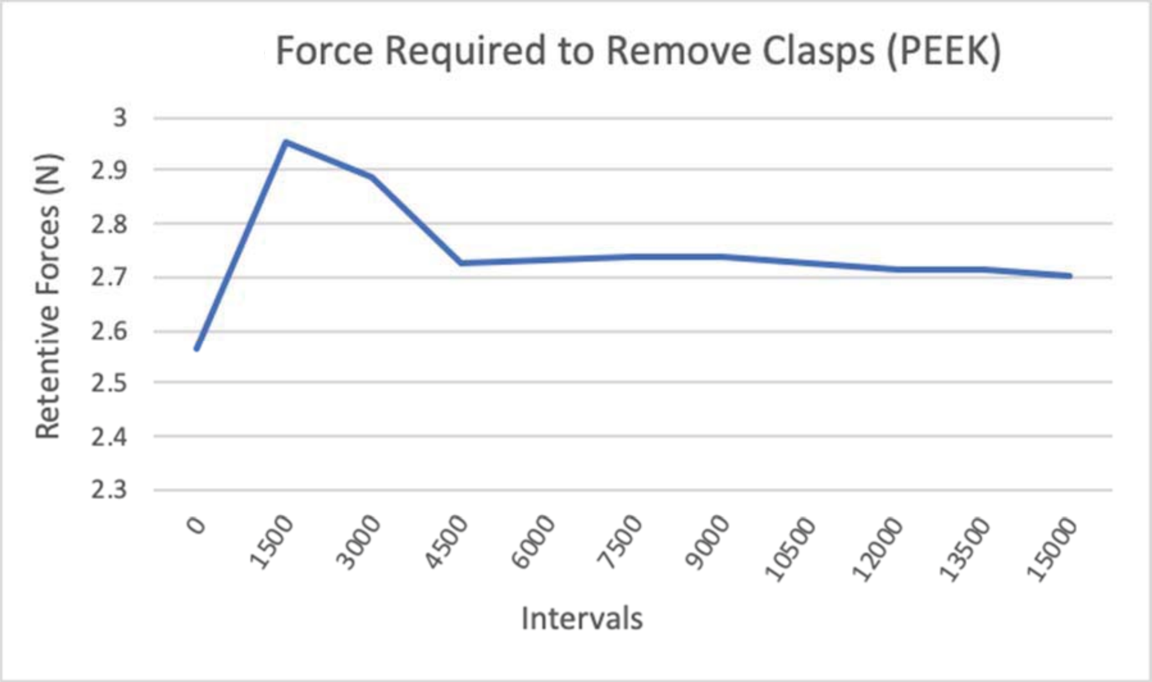

Fig. 8 – Changes in mean force required to remove PEEK clasps.

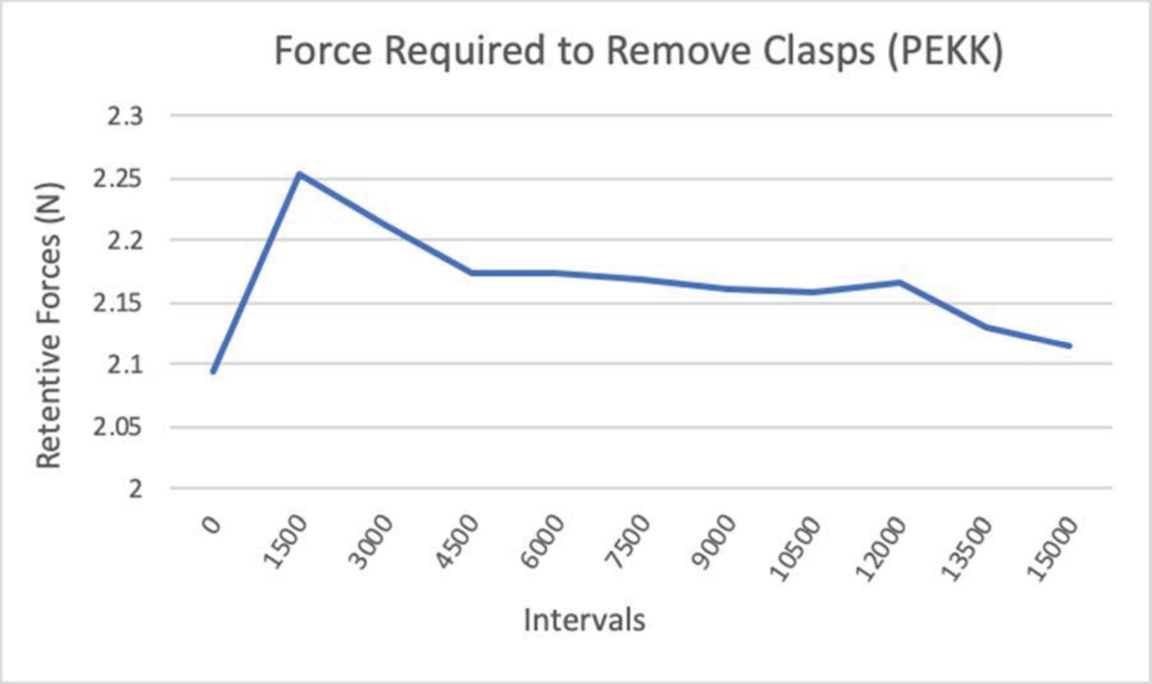

Fig. 9 – Changes in mean force required to remove PEKK clasps.

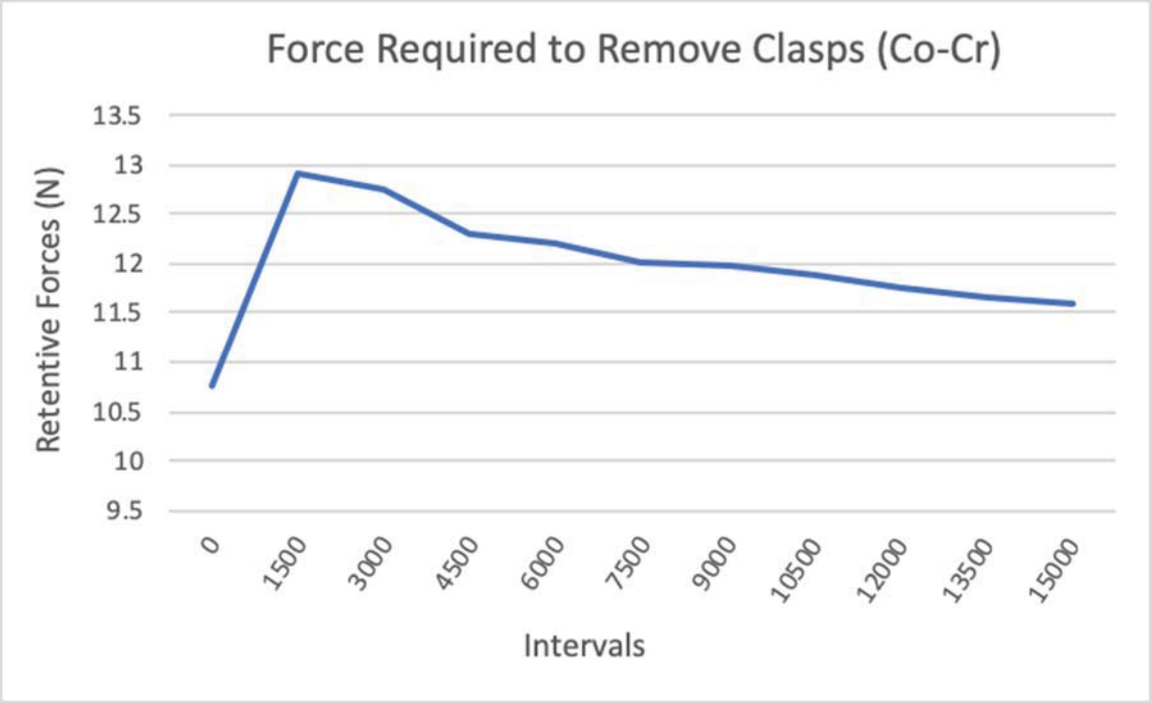

Fig. 10 – Changes in mean force required to remove CoCr clasps.

Chapter IV: Discussion

In this study, mean retentive forces of CoCr clasp assemblies were significantly higher compared to thermoplastic polymer clasp assemblies, therefore, the null hypothesis was rejected. Although the retentive force values of both thermoplastic polymers were significantly less than CoCr, the mean retentive force values of both PEKK and PEEK were similar to a previous study that evaluated retentive forces of thermoplastic polymer clasp assemblies (Tannous et al., 2012).

The greater forces required to remove CoCr clasps is most likely due to its higher initial stiffness compared to thermoplastic polymers. Additionally, as shown in Fig. 7, the retentive forces for the polymers were relatively consistent over the 15,000 cycles. The initial rise in retentive forces seen after the first cycle for all materials may be attributed to wear occurring between the abutment tooth and clasp, thereby, creating surface roughness and increased friction (Tannous et al., 2012).

In this study, the polymer clasp assemblies were designed according to the manufacturers' recommendations and an undercut of 0.25mm was utilized. Thermoplastic polymers have a low modulus of elasticity and therefore are more flexible compared to traditional CoCr alloys. This increased flexibility may allow for engagement of deeper undercuts compared to CoCr and, therefore, increased retentive forces. The mean retentive forces of both PEKK and PEEK in this study were below the acceptable range of 3-7.5N as reported in a previous study (Frank and Nicholls, 1981). However, there is not a consensus on the minimum retentive forces needed as many variables affect the retention of an RPD. Some of these factors include: contour of abutment teeth, depth of undercut engaged, cross-section and length of retentive clasp, and clasp material.

Limitations of this study include, evaluating single clasp assemblies in only a vertical removal and insertion direction. As more components of an RPD are added, to include major connectors, additional clasps, and guide planes, the rigidity of the RPD and overall retentive forces may increase. Additionally, in a clinical environment, patients may insert and remove the RPD along different paths which may act to deform clasps more rapidly compared to the purely vertical forces utilized in this study. Considering their resistance to fatigue, ability to be fabricated with a CAD-CAM workflow, and non-metallic coloring, polymer RPDs are an acceptable clinical alternative to CoCr RPDs.

Chapter V: Conclusion

Within the limitations of this study, it was demonstrated that thermoplastic polymer clasps demonstrated significantly lower retentive forces compared to CoCr clasps, however, their retentive forces were relatively constant throughout 10 years of simulated insertion and removal.

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