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COMPARATIVE STUDY OF RETENTION OF COBALT CHROMIUM AND NICKEL TITANIUM CAD/CAM REMOVABLE PARTIAL DENTURE CLASPS: AN IN-VITRO STUDY

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ABSTRACT

Objective: was to evaluate the retentive force of clasps made from two materials cobalt chromium and nickel titanium. **Material and methods**: Each of the fourteen enhanced dental stone models has a missing mandibular 1st, 2nd premolar, and 1st molar. Clasp abutment was utilised on the second molar. According to the materials used, the models were classified into two groups: group I (GI) for nickel titanium (Ni-Ti) and group II (GII) for cobalt chromium (Co-Cr). Each testing model and its clasps were placed within a univ ersal testing machine, and the retention was determined by applying a 5 mm/min withdrawal force to it. Removal and insertion cycling of clasps was carried out for 730, 1460, 2190, and 2,920 cycles (corresponding to 6, 12, 18 and 24 months of simulated clinical use of a RPD) to simulate the retention test. **Results:** Retention, after 730, 1460, 2190, and 2,920 cycles totally the difference between Ni-Ti and Co-Cr groups was statistically non-significant (P =0.03575>0.00272) where (Co-Cr > Ni-Ti). **Conclusion:** When compared to nickel titanium partial denture clasps, cobalt chromium removable partial denture clasps have larger retentive forces. Nickel titanium removable partial denture clasps may be a good substitute for cobalt chromium removable partial denture clasps.

KEYWORDS: Retention, Fatigue resistance, Deformity, Nickel titanium, Partial Denture.

INTRODUCTION

Removable partial dentures (RPDs) are one of the most used methods for replacing lost natural teeth. RPDs must have enough retention and flexibility, which are two of the most critical aspects influencing clinical effectiveness. The direct retainers' retentive clasp arms must be flexible and should maintain the RPD properly without putting undue stress on the abutment teeth or being irreversibly distorted during use. RPD direct retainers made of elastic materials showed a stronger resistance to retention loss [(1)].

The most popular metal alloy used to fabricate the direct retainers of RPDs is Co-Cr, however other alloys like as gold, titanium, and round wrought wire can also be utilised [(2)]. The load capacity of a clasp is determined by a number of elements, including the clasp's kind, position, tooth position, clasp length, and pullout location. The amount of retention

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required to remove the RPD from the supporting structure should always be the bare minimum required to resist realistic dislodging forces [3].

The material type of a clasp affects its flexibility and, as a result, its retention. This study will examine the retention of cobalt chromium (CoCr) and nickel titanium (NiTi) clasps. In the realm of dentistry, cobalt chromium is a well-known alloy. Oral tissue has a high strength, resistance, and biocompatibility due to its high strength, resistance, and biocompatibility [4].

Titanium alloys are also widely used in dental prosthetics. Because of its outstanding shape memory and elastic properties[5]. Nickel titanium has the unusual ability of recovering after elastomer deformation and remaining constant until proportionate limits are reached[6]. The loss of mechanical properties of a material with repeated loading is a significant factor to consider when choosing an alloy for RPD production[7]. Clasp fatigue affects retentive characteristics, and loss of retention can lead to clasp irreversible deformation, according to certain research utilising continuous deflection tests[8]. Because there isn't enough research on this issue yet, it's difficult to say how important NiTi is in the manufacture of removable partial dentures. As a result, conducting this research to compare the retentive forces, fatigue resistance, and deformation of milling NiTi clasps and traditional CoCr clasps will be advantageous.

MATERIALS AND METHODS

Fourteen enhanced dental stone models were created, each with a missing mandibular 1st, 2nd premolar, and 1st molar. Clasp abutment was utilised on the second molar. A largely edentulous patient with missing mandibular 1st, 2nd premolar, and 1st molar was chosen from the Al-Azhar University, Cairo boys' removable prosthodontic clinic as an outpatient. Using silicone impression material and a stock tray, a mandibular final impression was created (GC Corp, Tokyo, Japan). The imprint was then filled with a better dental stone (GC Fujirock EP; GC Corp). Finally, a better stone model was created with an edentulous saddle between the mandibular canine and the second molar.

A hemi-arch segment depicting a partly edentulous mandibular model with edentulous saddle between mandibular canine and 2nd molar was built from the modified stone model to prepare the selected model for the simulation testing. The abutment for the Aker clasp was the 2nd mandibular molar. The mandibular second molar was prepared for surveying the whole metal crown using the selected hemi-arch model section as the research model. The chosen model was placed on the surveyor table without being tilted. The surveyor's analysing rod was aligned with the long axis of the chosen tooth, and a carbon marker was used to estimate the height of the contour of the chosen tooth [9].

The selected tooth was prepared in order to receive the complete metal crown via occlusal preparation and removal of the undercut areas. Then, the selected hemi-arch model with the molar preparation was duplicated twice using silicone impression material. Impressions were cast with improved dental stone, and a complete crown was waxed up on each preparation [10].

The occlusal plane of each cast was oriented horizontally. With the occlusal planes oriented horizontally, the wax crowns were surveyed, and a 0.75mm retentive undercut area on the distobuccal surface of each wax crowns was created with a wax carver and was measured by means of the undercut gauge on the dental surveyor [10].

Both wax crowns were transformed into RPD abutments. The rest seat preparation was triangular in form, with the base of the triangle resting on the marginal ridge and the rounded tip pointing toward the centre of the tooth's occlusal surface. One-third of the space between the buccal and palatal cusp points was covered by the rest seat preparation. The occlusal rest seat's prepared depth was 2 mm. The rest seat preparation's floor was spoon-shaped and pointed toward the tooth's occlusal surface's centre. A surveyor blade was used to produce mesial and lingual guide planes that were two-thirds the length of the crown to standardise the insertion path. [4]. A ledge was placed on the buccal surface to standardize the locations and lengths of the retentive arms. On the palatal surface, a piece of wax, rectangular in shape, was placed as a reference to standardize the locations and lengths of the reciprocal arms [11]. The waxed complete crowns patterns were sprued at the thickest part of the crown wax pattern with 8-gauge sprues (Kunststoff-Guskanalstifte; Degussa, Krefeld, Germany).

The wax patterns were invested in casting rings. Investing of the wax patterns was carried out after application of the surface-tension reducing solution to the wax patterns. The investing procedure was done using a phosphate-bonded casting investment material. The investment paste was poured into casting rings which containing the sprued complete crown wax patterns, until it covering thoroughly the wax pattern and sprues [11].

After the complete set of the investment, it was burn in the furnace to eliminate the wax leaving a mold. Then, the mold was casted using a Ni/Cr alloy in an induction cast apparatus (Neutrodyn EasyTi; F.lli Manfredi S.p.A., Torino, Italy), under vacuum and argon-inert atmosphere, with the molten alloy injected into the mold by centrifugation according to the manufacturer's specifications [12]. After casting, the modified complete crowns were removed from the cast and subjected to air-particle abrasion with aluminum oxide (80 psi 5.62 kgf/cm^2).

The Ni/Cr modified complete crowns were finished and polished with blasting machine with aluminum oxide with a grain size of 50 μm at an air pressure of 0.4 MPa for 30 seconds (After finishing and polishing of the modified complete crowns, they were then cemented in place on the selected tooth with zinc phosphate cement [4] (Elite cement 100; GC Corp). The vertical path of insertion for RPD clasps was determined for each cast, and unwanted undercut regions were blacked out. To standardise the position of clasp arms, ledges were etched into the block-out material. The retentive undercut was engaged by the clasp's terminal one fifth (2 mm). Index castings were marked with tripod markings for subsequent repositioning [13].

The cast was imprinted with a cemented abutment modified full crown, each with a retentive undercut. Using a phosphate-bonded casting investment material, impressions were poured to create refractory dies. For this investigation, a separate refractory die was poured for each clasp[10].

Preformed semicircular clasp designs were used to create wax circumferential clasps with mesial occlusal rests, minor connections, and little residual ridge bases (Protek wax pattern, Molar clasp wfl mk; Bredent, Senden, Germany). Prior to creating definite imprints, the designs were modified along ledges produced with block-out material. Clasps were extended to the angles of the distal line. A 1.4mm retentive arm was employed [10].

A surveyor was used to attach a circular plastic sprue (Kunststoff-Guskanal-stifte; Degussa) to the remaining ridge base parallel to the line of insertion. This sprue was then utilised in the universal testing machine to keep clasp test items in place [10].

Each assembly (die and pattern) was cast in the same investment material used to create the dies in a casting ring. The designs for the clasps were then cast. The manufacturer's instructions were followed while investing and casting phosphate-bonded material. Sequential finishing devices, such as green stone points (Dura-Green; Shofu Dental Corp, Tokyo, Japan), white stone points (Dura-White; Shofu), and silicone rubber points (Silicone-point; Shofu), were used to polish the exterior surfaces of clasp assemblies (4). Clasps were then airborne-particle abraded for 30 seconds with 50m alumina oxide at 0.4 MPa air pressure. Nodules and burs were removed during the polishing step. Care was taken to avoid abrading the intaglio surface of the retentive arms[4]. For Co/Cr material, a total of 14 clasps were made. All specimens were radiographically checked before to the test to detect any probable casting faults that would exclude their use in the retention test [(20)]. Each clasp was examined for flaws in the casting and porosity[(4,10)]. All specimens were radiographically analysed for interior porosity using a dental X-ray equipment (FCR5000R radiographic unit; Fuji Photo Film Co, Ltd, Tokyo, Japan). Before testing the Co/Cr Aker clasp, a digital impression was taken using a digital camera (medit i700) of the clasp assembly, paying specific attention to the connected plastic sprue. Also, a digital impression of the hemi-arch segment “selective model” was made [(7)].

Computer-aided design (CAD) software was used to create a three-dimensional picture. The Aker clasp was then designed using CAD software (3Shape Dental System, version 2.9.9.3), which also generated a standard triangulation language (STL file)[(19)]. The path of insertion of the Aker clasp was determined on the digital file, and the survey line was drawn with digital block-out for the undesirable undercuts [(19)].

The full clasp assembly design was then created digitally in 3D format, and the various clasp assembly components were included. The standard triangulation language (STL) file was then used to make the Ni/Ti Aker clasp from Ni/Ti alloy blocks using a computer-aided machine (CAM) (Redon milling machine) [(16)]. At the pre-test (Baseline), the withdrawal force of each clasp was measured using this equipment at a rate of 5 mm/min. ROBOTA chewing simulator coupled with thermo-cyclic protocol controlled on servo-motor (Model ACH-09075DC-T, ADTECH TECHNOLOGY CO., LTD., GERMANY) was utilised to execute retention via removal and insertion cycling. Each clasp specimen was then put on the appropriate abutment and secured to the machine’s top section with a vertical rod. The test settings were kept at room temperature (25°C) and in a moist state. To replicate the fatigue resistance test, clasps were removed and inserted for 730, 1460, 2190, and 2,920 cycles (equivalent to 6, 12, 18, and 24 months of simulated clinical usage of an RPD)[(14)] , (Figure 2).

The magnitudes of retentive force at various intervals were tabulated and statistical analysis was performed. The data was analysed in numerous stages. To begin, descriptive statistics for each group’s findings. To discover significant impacts of each variable, a 2-way ANOVA test and a multi-factorial ANOVA test were used (material group, tooth support and mechanical aging). Between subgroups, paired and unpaired t tests were used. Graph Pad In stat (Graph Pad, Inc.) for Windows was used for statistical analysis. In all tests, P values less than 0.05 are considered statistically significant.

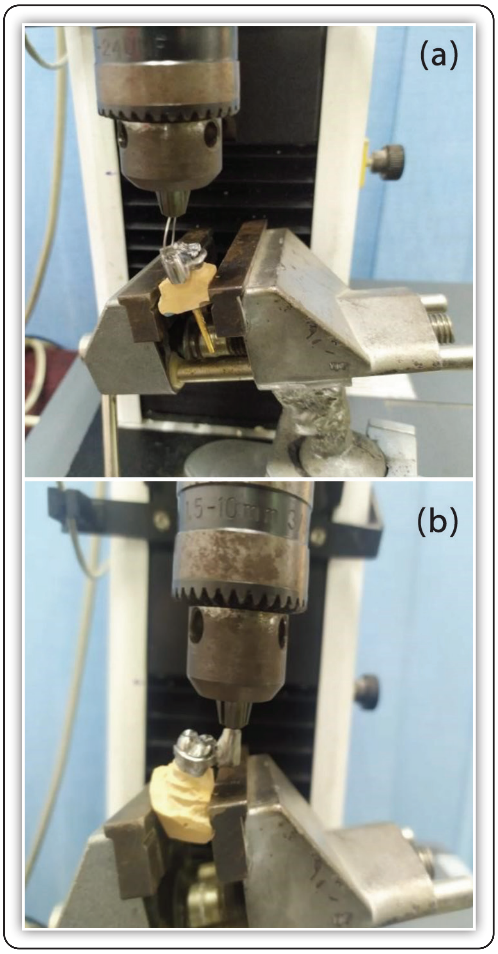

FIG (1) Each clasp and its model were mounted on the universal testing machine, (a) Co-Cr clasp, (b) Ni-Ti clasp.

FIG (2) Each clasp and its models were mounted on the chewing simulator device.

The acceptance of ethical committee is EC Ref No.146/161/04/05/19.

RESULTS

Retention

The informative statistical analysis which showing mean values and standard deviation (SD) of retention test results measured in newton (N) for Ni/Ti and Co/Cr clasps are summarized in Table (1)

The statistical analysis of retention of the both tested groups revealed that; the difference between the two tested groups was non-statistically significant as indicated by t-test at base-line (t=0.9068, P=0.19549), after 730 cycle (t=1.8, P=0.05477), and after 2190 cycle (t=0.3805, P=0.35673).

While, the statistical analysis of retention of the both tested groups revealed that; the difference between the two tested groups was statistically significant as indicated by t-test at 1460 cycle (t=3.771, P=0.00272), and after 2920 cycle (t=2.0764, P=0.03575).

Where; the lowest (mean ± SD) values of retention was recorded after 2920 cycle for the Ni/Ti and Co/Cr clasps (0.54±0.23 N), and (1.18±0.64 N) respectively, followed by 2190 cycle with mean ± SD values of (1.86±0.27 N), and (1.94±00.38 N), and 1460 cycle with mean ± SD values of (2.36±0.15 N), and (2.84±0.24 N), then at 730 cycle with mean ± SD values of (3.58±0.19 N), and (3.76±0.11 N), for both of Ni/Ti and Co/Cr clasps respectively. While, the highest (mean ± SD) value of retention was recorded at the base line with values of (3.9±0.15 N), and (4.08±0.41N) for both of Ni/Ti and Co/Cr clasps respectively.

TABLE (1) Descriptive statistics of retention results for both groups as function of evaluation time.

Variable	Group I (Ni/Ti) (Mean± SD)	Group II (Co/Cr) (Mean± SD)	t-value	P-value
Base-line	3.9±0.15	4.08±0.41	0.9068	0.19549 ns
After 730 cycle	3.58±0.19	3.76±0.11	1.8	0.05477 ns
After 1460 cycle	2.36±0.15	2.84±0.24	3.771	0.00272*
After 2190 cycle	1.86±0.27	1.94±00.38	0.3805	0.35673 ns
After 2920 cycle	0.54±0.23	1.18±0.64	2.0764	0.03575*

**; significant at $P < 0.05$; non-significant at $P > 0.05$. ns= non-significant.*

DISCUSSION

Comprehensive treatment plans for partly edentulous individuals are typically more difficult than treatment plans for edentulous patients or people who do not need their missing teeth replaced[7]. Various metals have been investigated for the manufacture of removable partial denture (RPD) frameworks since the debut of lost-wax casting. The most often utilised materials are gold and cobalt chromium (Co/Cr) alloys[11]. As a result, Co/Cr was chosen as the control clasp material in this investigation. This is due to the fact that Co/Cr alloys offer a variety of properties, including high resistance and strength, compatibility with oral tissues, and a lower total weight[5].

Despite advances to Co/Cr alloys and the fact that these alloys are the most commonly used for casting RPD metallic frameworks, the quest for the perfect material for manufacturing RPD remains a problem, and the usage of titanium for the fabrication of cast RPD frameworks has progressively grown[10] .

Nickel-titanium alloys have unique mechanical features, such as shape memory and elastic qualities, which means that when the alloy is stretched, the stress value remains relatively constant up to the proportionate limit. When the alloy recovers from elastic deformation, the stress value remains relatively constant, which is a unique attribute of the Ni/Ti alloy[4]. As a result, Co/Cr was chosen as the test clasp material in this investigation. This is attributed to its superior biocompatibility, capacity to recover from deformation, and corrosion resistance than Co/Cr. Clasp removal and insertion cycling was performed for 730, 1460, 2190, and 2920 cycles in this study. Furthermore, at 0, 730, 1460, 2190, and 2920 cycles, the retention force was defined as the highest load that necessitated releasing the clasp. These test requirements were chosen to correspond to six, twelve, eighteen, and twenty-four months of simulated clinical RPD usage [10]. Wax crowns with a 0.75-mm retentive undercut depth were employed in this investigation. This is because it was previously noted that the 0.75 mm undercut depth dimension might be employed to solve an RPD framework design challenge, such as when a more cervical (gingival) clasp position is required for cosmetic reasons [19].

Although there is evidence of the 0.75-mm undercut being contraindicated for Co/Cr alloys, there are reports stating that larger undercuts could be used for flexible clasps such as Ni/Ti [9], which explains its use in this study. One might expect that the clasps with the 0.75 mm undercut to have exhibited more permanent deformation than the clasps for the lesser undercuts [9].

The metallic crown on the lower second molar was employed in this study to assess the retentive force and fatigue resistance of Co/Cr and Ni/Ti clasps. This is in line with a recent research that aimed to make clasp testing easier on the universal testing equipment [19].

In comparison to Co/Cr clasps, Ni/Ti clasps exhibit lower retentive forces, according to the findings of this study. This might be due to the Ni/Ti clasp's increased flexibility [7].

Furthermore, the findings of this investigation revealed that the difference in retentive forces at baseline and after 730 cycles was not statistically significant (P= 0.19549 and 0.05477). This might be connected to the depth of the undercut, where the greater depth could play a role in the flexible Ni/Ti clasps' retention[4,5,19]. Furthermore, the low modulus of elasticity of Ni/Ti, combined with bigger retentive undercuts than advised for Co/Cr, favours Ni/Ti retention over Co/Cr retention [20].

However, the current study's findings in terms of retention demonstrated a statistically significant difference in retentive forces between Co/Cr and Ni/Ti clasps at the conclusion of the study period, or after 2920 cycles (P= 0.03575). Because the insertion route was precisely regulated by the testing apparatus and the guidance planes of abutment teeth, this was most likely caused by the clasps' extended cold operation(4,18). Furthermore, the cold working that was imposed on the material during production, as well as the cold working that was performed during testing, might play a significant influence in reducing the flexibility of the Ni-Ti clasps(5, 7).

In addition, the adoption of a deeper undercut in the current investigation, along with the clasps' extended cold functioning through multiple insertion and removal cycles, might explain the considerable decrease in retention of the Co/Cr and Ni/Ti clasps(18). This confirms the findings of earlier research, which showed a loss of retention due to irreversible deformation of the Co–Cr clasps.

CONCLUSION

When compared to nickel titanium partial denture clasps, cobalt chromium removable partial denture clasps have larger retentive forces. Nickel titanium removable partial denture clasps may be a good substitute for cobalt chromium removable partial denture clasps.

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