Retention of Different Types of Attachments Used with Unilateral Implant Retained Mandibular Removable Partial Dentures

Seham E. Mohamed*[1] and Sahar A. Ghorab[2]

Abstract:

The association between removable partial dentures (RPD) and implants is greatly valuable, especially for class I and II Kennedy classification. Proper design, with splinting of the implants and employing attachments avoids unilateral RPD compromises.

The aim of this in-vitro study was to evaluate and compare the retention of Ball attachments and OT Equator attachments used with two splinted implants retaining unilateral mandibular (RPDs).

Materials and methods: 4 identical experimental models were fabricated and categorized into two groups according to the type of attachment used (Group I) with Ball attachments and (Group II) with OT Equator attachments. Each model received two root-form implant analogs, one at the second premolar area and one at the first molar area. These two implants were splinted together by a metal superstructure, with attachments used to retain the unilateral RPD. Retention of the two groups was tested and compared using a Universal testing machine.

Results: In (group I), the mean retention ± standard deviation decreased from 8.07 ± 0.86 at baseline to 5.61 ± 0.74 after 450 cycles, then decreased again to 3.13 ± 0.71 after 900 cycles. In (group II), the mean retention ± standard deviation decreased from 9.89 ± 0.93 at baseline to 6.51 ± 0.90 after 450 cycles, then decreased again to 5.62 ± 0.38 after 900 cycles.

Conclusion: OT Equator showed higher retention rates than Ball with significant differences between them after 900 cycles of insertion and removal representing 6 months usage of the implant retained unilateral RPDs.

Keywords: Unilateral RPD, implant retained RPD, Ball attachment, OT Equator attachment, retention of RPD.

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*[1]Lecturer in Removable Prosthodontic Department, Faculty of Dentistry, Ahram Canadian University.

[2]Associate Professor in Removable Prosthodontic Department, Faculty of Dentistry, Ahram Canadian University.

Introduction

Although the recent trend is towards dimensioning edentulism in general, the group with the massive need for complete or partial oral rehabilitation is the growing elderly population[1]. Conventional RPDs as a treatment option for partial edentulism, especially those with mandibular distal extension cases, present their own set of complications, such as uneven support, poor retention and stability, rotation around the distal abutment, discomfort, needing periodic relining to avoid traumatic occlusal forces leading to ridge resorption or compromising abutment teeth, with difficulties in hygiene maintenance[2].

One of the alternative treatment options to decrease the complicated conventional designs and excessive tissue coverage, especially in Class II RPDs is the unilateral design, enhancing esthetics and patient comfort with decreased coverage. However, the rotational tendency after usage and torque of the last abutment is inevitable, regardless of how meticulous is the design and retention means[3].

Implant-assisted RPDs are a good solution for many distal extension problems, particularly in unilateral cases. Despite the rapid innovative changes in this treatment option, a few complications are still associated with it. Such complications may result from the design, the type of bone, the number of implants inserted, their angulation, and their location[4]. In many partially edentulous patients having resorbed ridge, implant treatment needs complex techniques, such as transposition of the nerve, grafts, or change the position or implant length. One of the solutions in such cases is the All on X concept, which requires the distal implant to be at an angle allowing the utility of longer implants, enhanced anchorage with the bone, and better prosthetic sustenance with a shorter cantilever arm without endangering the vital tissues in proximity[5].

Using different attachments with implants was found to improve the retention, support, and stability of removable appliances, thus extending their longevity and serviceability. Attachments provide enhanced esthetics lacking visible metallic components, and improve stress distribution[3].

The selection of a convenient attaching mechanism is governed by the amount of retention needed, the condition of the residual bone, inter-arch distance, the status of the antagonistic jaw, and the patient's expectations. Resilient stud attachments became a favorable treatment option, due to their easy usage and simple maintenance. Different types of stresses may lead to surface behavior changes, nylon cap distortion, wear, and even breakage of attachment parts. To select proper retention and the least wear behavior, several attachments are presented in the market to choose from[6].

Ball attachment is the commonest as it is the simplest form of all studs, it is practical, effective, relatively low cost, less technique sensitive, easy to manipulate, minimal chair side time, and possible applications with both root and implant-supported prostheses[7].

OT Equator attachment is a custom attachment design, ideal for matching difficult implant rehabilitation cases, which syndicates the ball attachments simplicity and provides several exclusive benefits[8]. A significantly lower profile the thus lesser visibility, and smaller diameter, solving the problem of non-parallel implants, hygienic design, and reasonable price are the primary advantages[9].

It is well established that attachment's loss of retentive force over time is inevitable and attributed to wear of its different components, regardless of their initial retention level[10, 11]. This research aimed to in-vitro evaluate and compare the retentive force of Ball attachment and OT Equator attachment used with two splinted implants retaining unilateral mandibular removable partial dentures. This implant retained RPD design will be a conservative solution sparing the remaining teeth.

Materials and methods:

This study was conducted after the regulations and approval of the ethical committee of Ahram Canadian University, Faculty of Oral & Dental Medicine number IRB00012891#55.

Epoxy Resin Model Preparation:

The study was performed on clear epoxy resin acrylic models (Kemapoxy 150JM, chemical for modern building international CMB, Egypt) representing a partially edentulous mandibular arch with class II in which the last standing tooth is the left first premolar. 4 identical experimental models were constructed (2 models / group), then the two groups were randomly categorized into (Group I) with Ball attachments (Rhein83, Bologna, Italy) and (Group II) with OT Equator attachments (Rhein83, Bolonga, Italy).

Plateauing of the ridge area of the casts is performed to create a diameter of at least 5 mm using straight hand piece. All surfaces were smoothed (finished and polished) with fine sandpaper.

Epoxy resin models were marked at two points one at second premolar and one at the distal root of first molar areas then drilled by tungsten carbide bur (laboratory tungsten carbide bur) to create an osteotomy to receive two root form implant analogs (RC regular cross fit), bone level implant analog (Titanium, L:8mm, D:4.2mm, Root, Egypt) with the diameter and length of (4.2 x 8mm). The implant placed at the second premolar area was inserted perpendicular to the ridge crest of the model but the implant at the first molar area was inserted with a 30° angel distally. The implant analogs were fixed to the models using flow mix of self-cured acrylic resin and flushed with the ridge. A metal framework was fabricated from the plastic model provided by (Rhein83, Italy) to splint the two implants together as shown in figure (1).

Figure (1) showing the plastic model of the splinting framework

The conventional steps of RPD construction were then followed. After RPD finish and polish, the identical and fitted partial dentures were ready for pick up steps.

The attachments used with the models were screwed to the framework by the screwdriver as in figure (2). A block out spacer ring was adapted around each attachment. Then, a metal cap with a processing part was seated onto every attachment and was pressed down to ensure engagement of the attachment.

Figure (2) showing the OT Equator Attachment

Using a fissure bur, relief (vents) were made in the fitting surface of the denture corresponding to the position of the attachments to create sufficient space for the acrylic resin during the pick-up procedure. Cold-cure acrylic resin was mixed according to the manufacturer's instructions and placed in the fitting surface at the vent's sites. The denture was seated over the caps and was left until the material set. RPDs were removed then finishing and polishing of the acrylic pick up was done.

The retention caps of the two types of attachments were chosen to be nearly with the same retention amount to standardize the testing conditions.

Retention assessment:

Geographic center:

The assessment of RPD retention is accurately performed by pulling it in a vertical direction perpendicular to its path of insertion, from the denture's geographic center. Two metal chains were attached at two points buccal and lingual to the antro-posterior denture's center, then the chains were attached together above the dentures by one common ring in which a small metal rectangle is attached to be held in the testing machine instrument. The metal rectangle and the chains were checked several times before starting the trial as it must be inserted passively without exerting any force to avoid false readings.

Figure (3) showing the pulling action of the testing machine

Retention Measurements by universal testing machine:

Successive dislodging forces were applied by the Universal testing machine (Shimadzu Testing Machine, EZ-X Series, SUZOU Instruments. MANUFACTURING Co., Ltd.) running at 0.5 mm/min. The retention force was determined for the samples at baseline and after; 450, and 900 cycles. The samples were submitted to tensile strength tests by locking the models on the table (lower compartment) of the machine with tightening screw, then gripping the rectangular metal bar arising from the chains with the upper compartment of the testing machine and pulling upwards till separation of the denture occurs. The loose position was recorded by the machine as the zero position or the starting point. The machine was started, and the software recorded the amount of force required to completely remove the denture from the epoxy cast at the previously mentioned speed.

Data was displayed and recorded by computer software and the load required to totally dislodge the denture was recorded in Newton, as shown in figure (3). The records were repeated for each model 10 times obtaining 10 readings. The dentures were then inserted and removed manually 450 times representing 3 months of usage, then another 10 readings for each denture were recorded. Again, each denture was inserted and removed manually another 450 times representing 6 months of usage, then the last 10 readings were recorded. All readings of each group were statistically analyzed.

The environmental conditions during testing, as temperature and humidity were standardized, as these factors can influence attachment retention. Special considerations were taken to relevant factors that may affect the attachments retention such as wear, tear, material properties and manufacturing tolerances.

Statistical analysis:

Data were presented as mean and standard deviation of the retention force for each attachment system. Statistical analysis was performed with SPSS 25.0 ® (Statistical Package for Scientific Studies). Exploration of the given data for normality distribution was performed using Shapiro-Wilk test and Kolmogorov-Smirnov tests, which revealed normal distribution with the significance level (P-value) to be insignificant when P-value > 0.05. A comparison between different measurement values within the same group was performed using ANOVA test. Comparison between the mean difference in the two groups regarding retention of the two attachment types, was performed by using the independent t-test.

Results:

The average tensile force value required to displace the dentures at baseline in (group I) was 8.07 N. with a standard deviation of 0.86

N., while in (group II) it was 9.89 N. with a standard deviation of 0.93 N. The average tensile force value required to displace the denture after 450 insertion and removal cycles in (group I) was 5.61 N. with a standard deviation of 0.74 N., while in (group II) it was 6.51 N. with a standard deviation of 0.90 N. The average tensile force value required to displace the denture after 900 insertion and removal times in (group I) was 3.13 N. with a standard deviation of 0.71 N., while in (group II) it was 5.62 N. with a standard deviation of 0.38 N.

In (group I) (Ball): the mean retention ± standard deviation decreased from 8.07 ± 0.86 at baseline to 5.61 ± 0.74 after 450 cycles, then decreased again to 3.13 ± 0.71 after 900 cycles. These results revealed significant difference between retention at baseline and retention after 450 cycles, also between retention at baseline and retention after 900 cycles as P<0.05. But the difference in retention between 450 cycles and 900 cycles was insignificant as P>0.05.

In (group II) (OT equator): the mean retention ± standard deviation decreased from 9.89 ± 0.93 at baseline to 6.51 ± 0.90 after 450 cycles, then decreased again to 5.62 ± 0.38 after 900 cycles. Comparison between different retention values revealed significant difference between retention at baseline and retention after 6 months of usage as P<0.05.

Comparing the two groups retention values revealed insignificant difference P>0.05 at baseline readings and after 450 cycles of insertion and removal of the dentures, while retention of (group II) (OT Equator) was significantly higher (P<0.05) than (group I) (Ball) after 900 cycles of axial pulling on the dentures as shown in table (1) and the bar chart in figure (4).

Time	Group I (Ball)		Group II (OT Equator)	
	Mean	SD	Mean	SD
Baseline	8.07	± 0.86	9.89	± 0.93
450 cycles	5.61	± 0.74	6.51	± 0.90
900 cycles	3.13	± 0.71	5.62	± 0.38

Table (1) shows mean retention values and standard deviation in both groups at different times

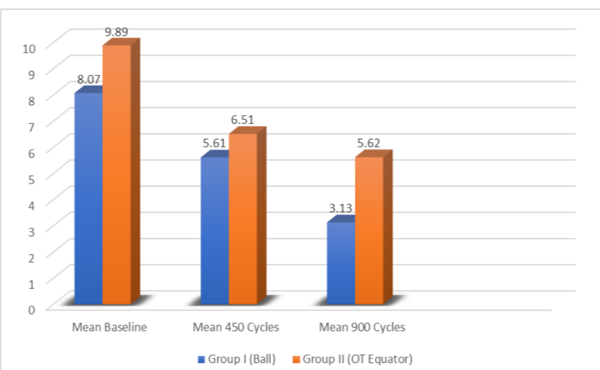

Figure (4) Bar chart representing the difference in retention values between the two types of attachments

Discussion:

In the present study Class II partial edentulism in a mandibular arch was chosen because partial edentulism is more prevalent in the mandible than in the maxilla, as for choosing Class II a previous study revealed that this type of edentulism and its restoration with RPDs is increasingly detected over the past 30 years[12].

It was recommended that plateauing of the acrylic cast is done to reach a proper width in order to easily insert the implant analogs, leaving reasonable space for each buccal and lingual surfaces of the analogs[13].

As it is known the simpler the design of the partial denture, the better the results will be, this means that every component of the partial denture must have a good reason for its presence; otherwise, it must be omitted. Applying this principle on the present study, it is better to use the unilateral design in Class II RPDs than the regular bilateral extended design because it has less components, more comfortable, less obtrusive, with better esthetics and protection of the remaining teeth.

Because of the small size of the unilateral RPD and the risk of not using any abutment tooth and totally depending on implants and attachments, this study was conducted in vitro and according to the findings it would be recommend conducting further research on the same design clinically to investigate its retention values and efficiency for long term use. Furthermore, it was conducted in vitro to overcome the limitations of measuring retention in vivo, with the difficulty of applying pure vertical pulling action intra-orally.

In unilateral RPD design, there are differences in support between hard and soft tissues, which creates appliance movement, with resultant harmful effects on underlying tissues. When vertical forces are applied, it will be transmitted unevenly to the investing structures due to the difference in the resiliency of periodontal ligament of abutment teeth and denture bearing mucosa[14]. That is why in this study it was chosen to use dental implants to overcome this problem and unify the supporting structure with no need for including any tooth as an abutment, to prevent undue torque exerted on the natural teeth if an extra-coronal attachment is to be used with the standard unilateral RPD. Thus, achieving optimal retention, support and stability which are critical considerations for unilateral implant retained RPD while sparing the remaining teeth.

A previous research considered that two implants were needed to avoid the use of a lingual bar and clasp on the premolar and to prevent rotation and displacement, it also concluded that using magnets as attachments with this design (without lingual bar or clasp) attained good clinical outcome for more than ten years[15]. For this reason, in the present study two implants were utilized to provide enough support and stability to the unilateral RPD.

It was stated that adequate retention could be achieved even though one of the implants was tilted[15]. In some cases of resorbed mandibular ridge, using posterior implants with distal angulation provides good bone support without interfering with vital structures[16]. That was supporting the idea of tilted distal implant in this study, with the application of the All on X concept to splint both implants together thus increasing support and retention.

A previous study referred that fixed implant restorations are not recommended when there is bone loss or few number of implants to be used because it may negatively affect esthetics, implant loading, occlusal stability, and screw retention[17]. Cement retained fixed restorations are indicated when crown height space is between 8-15mm. so less than this inter-arch space cannot be restored with fixed restoration[18]. For these reasons removable restoration is the best choice for those cases.

Many mechanical complications have been reported in association with implant retained removable partial dentures[15]. Furthermore several case reports showed that small unilateral dentures can induce swallowing and aspiration[19, 20]. Due to these reasons, a rigid and repairable structure is necessary to withstand forces applied on the implants and denture, that's the reason for splinting the two implants in the present study to increase the strength of the substructure. Also, incorporating attachments with the implants retaining the partial denture to allow for the needed retention and overcoming the swallowing problem.

In this study measuring the attachments retention involves assessing the resistance of these attachments to dislodgment or detachment in a vertical direction. It has been documented previously that measuring denture retention is more accurately performed by pulling it in a vertical direction from its geographic center[21].

The universal testing machine is well proved by literature as a reliable and reproduceable tool to replicate the vertical separation of a removable appliances from the mouth and test pulling forces in-vitro[22, 23]. The universal machine of testing was set with a 0.5 mm/min crosshead speed to simulate the speed of dislodging of a prosthesis during mastication[24]. The computer connected to the universal machine recorded the load of dislodgment of the two-attachment systems in the present study in a speed of 0.5 mm/min following the previous studies. The test was conducted on multiple samples in each group to ensure the reliability of the results.

In the literature there was no consensus considering the number of cycles the dentures should be subjected to, and different number of cycles had been used in variety of studies[11, 13, 25]. The tested overdentures in this study were subjected to 450, and 900 cycles of insertion and removal which simulate, nearly, three and six months of applied usage. Insertion and removal cycles simulation was calculated as a previous study stated by assuming that the patient removes and inserts his denture four times per day: once after each meal for cleaning and once before sleeping[25], with adding one more time for rinsing after a snack we assumed that average removal and insertion of the denture per day may be five times.

Both types of attachments used with the present design showed retention values more than 5 N., which is the least retention needed for a removable prosthesis to be considered effective for clinical use[11, 26].

In the present study there was gradual retention loss in both types of attachments used with a significant decrease in retention in each group between base line readings and after 6 months of use. There were also significantly higher retention values achieved with OT Equator attachment than the values achieved with Ball attachments after 900 cycles of insertion and removal representing 6 months of use.

It was noted by some research that decrease in retention of Ball attachments occurs as a result of attachment abrasion and micro-movements during the mastication process [7, 27]. Another study concluded that Ball attachment shows decreased initial retention forces than other types of attachments due to the greater resiliency of its parts[26]. It was reported also, that the ball attachment undergoes deformation more than the equator thus having less retention values[28].

Studies referred that it is valuable to use the unilateral RPD attachment OT Equator being simple and prevents bone resorption[29, 30]. Another study also stated that OT equator attachment has higher initial retentive power values than the ball attachment, and it should be used more when implants are nonparallel. Thus, for the greater retention OT equator attachment type should be the best choice for implant overdentures[23]. These results are in accordance with the results of the present study with increased retention in case of OT Equator attachment system than Ball attachment especially after 900 cycles of insertion and removal.

Limitations of the present study includes, retention was measured only in the axial direction with no consideration to the lateral and rotational forces during actual mastication, no saliva simulation was used, short period of cyclic insertion and removal of the dentures, and finally clinical conditions have many variables that were not tested in this in-vitro research.

Conclusion:

Within the limitations of this study, both attachment systems evaluated Ball and OT Equator used with totally implant retained RPDs, showed good retention values, within the required limits for retaining and stabilizing the prosthesis as they were higher than 5 N., and they are considered suitable for clinical use.

OT Equator attachment showed higher retention rates than Ball attachment at all interval times of testing, with significant differences between them only after 900 cycles of insertion and removal representing 6 months of use of the unilateral implant retained RPD.

It is recommended to clinically investigate this line of treatment with short- and long-term use.

Conflicts of interest

The authors declare that there are no conflicts of interest.

Funding

The research was totally funded by the authors.

References:

1. Douglass C. W., Shih A., and O. L., Will there be a need for complete dentures in the United States in 2020? J Prosthet Dent., (2002). **87**(1): p. 5-8.
2. Vahidi F. and P.-S. G., Complications Associated with Implant-Retained Removable Prostheses. Dent Clin N Am., (2014). p. 1-11.
3. Carr A. B., Mc Givney G. P., and B.D. T., Direct Retainers. In: McCracken's removable partial prosthodontics. . Vol. 12th ed. 2011: Missouri: Mosby. .
4. Al-Ghafli S. A., et al., The In Vitro Effect of Different Implant Angulations and Cyclic Dislodgement on the Retentive Properties of an Overdenture Attachment System. J. Prosthet. Dent., 2009. **102.**: p. 140-147.
5. Krennmair G., et al., Patient preference and satisfaction with implant-supported mandibular overdentures retained with ball or locator attachments: a crossover clinical trial. . INT J ORAL MAX IMPL., (2012). **27.**(6.): p. -15601568.
6. Fajri L., et al., Attachement locator en prothèse amovible complète stabilisée sur implants: description et mise en oeuvre pratique. African Journal of Dentistry & Implantology. , (2020). **27.**(16.).
7. Trakas T., et al., Attachment Systems for Implant Retained Overdentures: A Literature Review. . Implant Dent., (2006). **15.**: p. 24-34.
8. Ángel Vicente-Escuder Eduardo J. and S.-O. . In Vitro Retention Capacity of Two Overdenture Extra Systems: Locator ® And Equatorj. Clin Exp Dent. , (2018). **10.**: p. 681-686.

9. Payne A. G., et al., Interventions for replacing missing teeth: Attachment systems for implant overdentures in edentulous jaws. . Cochrane Database Syst Rev. , (2018). **10.**: p. CD008001.

10. Alsabeeha N. H., Payne A. G., and S.M. V., Attachment systems for mandibular two-implant overdentures: A review of in vitro investigations on retention and wear features. . Int J Prosthodont. , 2009. **22**: p. 429-440.

11. Reda K. M., El-Torky I. R., and E.-G.M. N., In vitro retention force measurement for three different attachment systems for implant-retained overdenture. . Journal of Indian Prosthodontist Society., 2016. **16**(4): p. 380-385.

12. Chamoko J. and K. S., Outcomes of mandibular Kennedy Class I and II prosthetic rehabilitation-An observational study. . South African Dental Journal., 2019. **74.**(10): p. 549-555.

13. Issa H. H., et al., Retention and Wear Evaluation of Locator Attachment and Novaloc Attachments for Two Implant-Supported Mandibular Overdentures (In Vitro Study). Br J Med Health Res., (2022). **8**(3): p. 16-28.

14. Liu R., et al., Conversion of a partial removable dental prosthesis from Kennedy Class II to Class III using a dental implant and semiprecision attachments. . J Prosthodont., (2012). **21.**(1.): p. 48-51.

15. Wada Y., Yoshimura H., and M. I., Combination of short implants and a unilateral distal-extension implant-retained partial denture in case of severely reduced ridge height mandibular posterior region: 12-year follow-up. The Journal of the Academy of Clinical Dentistry., (2017). **37.**(1.2.): p. 72-80.

16. Taruna M., et al., Prosthodontic perspective to all-on-4 concept for dental implants. . J Clin Diagn Res. , (2014). **8.**: p. 16-19.

17. Yi S. W., et al., Patient evaluation of treatment with fixed implant-supported partial dentures. Journal of Oral Rehabilitation., 2001. **28**: p. 998-1002.

18. Misch, C.E., Retionale for dental implants. . 3rd edn. ed. Text Book of Contemporary Implant Dentistry. 2008.: New Delhi: Mosby, Elsevier Publishers.

19. Starr, N.L., The distal extension case: an alternative restorative design for implant prosthetics. . Int J Periodontics Restorative Dent., (2001). **21.**: p. 61-67.

20. Gallas M., et al., Unnoticed swallowing of a unilateral removable partial denture. Gerodontology., (2012). **29.**: p. 1198-1200.

21. Mustafa, A.Z., Effect of the lingual ledge of neutral zone impression on the retention

and stability of mandibular complete denture in elders with atrophied alveolar ridge. . Tanta Dental Journal. , (2015). **12**(2): p. 111-118.

22. Fromentin O., et al., Testing the retention of attachments for implant overdentures–validation of an original force measurement system. Journal of Oral Rehabilitation. , (2010). **37.**(1.): p. 54-62.

23. Doaa A. Rostom and N.A. Ragheb., Retention and wear characteristic assessment of ot equator with smart box attachment versus ball attachment for mandibular two implant assisted over denture. In-vitro study. Egyptian Dental Journal., (2021). **67.**(4.): p. 3525-3532.

24. Aboutar S., Elkerdawy M., and F. A., Effect of cross arch stabilization on the retention of a unilateral distal extension partial denture using a resilient extracoronal attachment: (in vitro study). Egyptian Dental Journal., 2023. **69.**(2): p. 1501-1515.

25. Arnold C., et al., Retention Force of Removable Partial Dentures with CAD-CAM-Fabricated Telescopic Crowns. Materials., 2020. **13**(3228.): p. 1-13.

26. Choi J. W., et al., Retention and wear behaviors of two implant overdenture stud-type attachments at different implant angulations. . The Journal of prosthetic dentistry. , (2017). **117.**(5.): p. 628-635.

27. Da Fontoura Frasca L. C., et al., Evaluation of retention forces and resistance to fatigue of attachment systems for overdentures: Plastic and metal components. . Implant Dent., 2014. **23**(4): p. 451-455.

28. Abi Nader S., et al., Effect Of Simulated Masticatory Loading On The Retention Of Stud Attachments For Implant Overdentures. . J Oral Rehabil., (2011). **38.**: p. 157-164.

29. Yang T. C., et al., Attachment Systems for Implant Overdenture: Influence of Implant Inclination on Retentive and Lateral Forces. Clin. Oral Impl. Res. , (2011). **22.**: p. 1315-1319.

30. Afify M., Helmy M., and A. N., Evaluation of Biting Force of New Design of Extracoronal Castable Precision Attachment versus Conventional Partial Denture for Treatment of Unilateral Mandibular Distal Extension Area: A Randomized Controlled Trial. Macedonian Journal of Medical Sciences., (2020). **8**(D.): p. 23-28.

31. Andrei O. C., et al., Finite element comparative analysis of von mises stress levels in unilateral removable partial denture with and without distal implant. Appl. Sci., (2022). **12.**(5116.): p. 1-8.