INFLUENCE OF FABRICATION TECHNIQUE ON THE FRACTURE RESISTANCE OF 3-UNIT INTERIM FIXED DENTAL PROSTHESIS: AN IN VITRO STUDY.

Mostafa E. Elashkar, BDS,[1] Yehia S. Aboushady, BDS, MS, PhD,[2],[3] Mohamed T. El Halawani, BDS, MS, PhD,[4],[5]

ABSTRACT

INTRODUCTION. The fracture resistance of interim restorations influences their integrity and service in the mouth until the definitive restoration is delivered, they should demonstrate adequate strength, specially, when used for longer periods of time. The strength of interim restorations is influenced by the fabrication method and material .

OBJECTIVE. The aim of this study was to investigate the influence of fabrication technique on fracture resistance of 3-unit interim fixed dental prostheses made by conventional and computer-aided design and computer-aided manufacturing (CAD/CAM) techniques.

MATERIAL AND METHODS. Thirty-two 3-unit interim fixed dental prostheses (FDPs) were fabricated on epoxy resin models using 2 different techniques; CAD/CAM milling (group MIL, n=16) (Ceramill A-Temp; AmannGirrbach, AG, Austria), manual fabrication using self-activated poly methyl-methacrylate PMMA (group MAN, n=16) (Unifast III; GC Corp., Tokyo, Japan). The restorations were cemented on their corresponding models, subjected to cyclic loading and were loaded in a universal testing machine until fracture. Normality was checked using Shapiro Wilk test and Q-Q plots. Comparisons of the fracture resistance between groups using independent t test. Significance was inferred at p value <0.05.

RESULTS. All specimens survived cyclic loading, the mean fracture resistance of MIL group was (1141.10 ± 131.36 N), while that of MAN group was (516.93 ± 62.96 N). A significant difference was found between the 2 groups (p <0.0001.(

CONCLUSIONS. CAD/CAM fabricated interim restorations offers better mechanical properties over manually fabricated ones and are more suitable to use as long-term temporary restorations .

KEYWORDS. interim restoration, fixed dental prosthesis, CAD/CAM, fracture resistance.

RUNNING TITLE: Influence of fabrication technique on the fracture resistance of 3-unit interim FDPs.

1- Instructor of Fixed Prosthodontics, Department of Conservative Dentistry, Alexandria University, Alexandria, Egypt
2- Dean of Faculty of Dentistry, Alamein International University, Al Alamein City, Matrouh, Egypt.
3-Professor of Fixed Prosthodontics, Department of Conservative Dentistry, Alexandria University, Alexandria, Egypt
4- Lecturer of Fixed Prosthodontics, Department of Conservative Dentistry, Alexandria University, Alexandria, Egypt
5-Assistant Professor, Prosthodontics Department, Faculty of Dentistry, Alamein International University, Al Alamein City, Matrouh, Egypt.

***Corresponding author:**
mostafa_esmatelashkar@hotmail.com

INTRODUCTION

In prosthodontics, Interim restorations represent an indispensable part of the treatment (1), they serve several functions until the definitive treatment is completed (1,2), including pulpal protection, preserving gingival health, and positional and occlusal stability (3). They also help in assessing function and esthetics, to help determine the final form and shape of the definitive restoration (4) Interim restorations are sometimes intended to be used for longer periods of time, during occlusal reconstructions, or to help shaping of soft tissues, or during orthodontic, endodontic, or oral surgical procedures, where the restorations could face prolonged occlusal forces (5). Under occlusal stresses, The mechanical characteristics and strength of the material used determines the integrity of the interim restoration (6.(

Numerous interim materials are available for use. Polymethyl-methacrylate (PMMA) is the most common material used to fabricate temporary restorations (7), due to its reasonably good handling and mechanical properties, color stability and repairability (8). On the other hand, PMMA generates significant heat during setting, causing polymerization shrinkage and pulpal insult (9,10). Most of these restorations are fabricated in-office using impressions loaded with the mixed auto-polymerizing powder and liquid (11,12)

The chairside fabrication of temporary restorations usually requires additional finishing steps leading to longer chair time. it is dependent on the clinician's skills increasing the likelihood of errors. During proportioning and Mixing procedures, air bubbles and voids could be incorporated, negatively influencing the strength, surface texture and precise fit (13–15). In addition, studies have shown that these restorations demonstrated low flexural strength immediately after fabrication (13). The topic of strengthening manually fabricated temporary restorations has been investigated in several studies (16,17)

Computer-aided design and computer-aided manufacturing (CAD/CAM) have recently become available and may reduce many of these problems (18). The absence of polymerization shrinkage and exothermic reaction for the interim CAD/CAM materials is the main advantage (19). In addition, interim restorations manufactured using CAD/CAM technology reduce the chair time and produce superior outcomes (20)

This technology delivers interim restorations with high precision that cannot be easily achieved using manual techniques (21), the temporary restorations produced by CAD/CAM generally are made from preprocessed PMMA resin blocks (21,22). The polymerization process of the blocks occurs industrially in ideal standardized conditions controlled by the manufacturer, thus, material uniformity with no defects or voids can be obtained (18). CAD/CAM fabricated temporaries also have better marginal adaptation and are more color stable than conventionally fabricated ones (6,23). Thus, they may be more suitable to be used as long-term restorations.

Fracture is a frequent cause of failure of interim restorations, and may lead to extra appointments, expenses and treatment time, and discomfort for the patient (24). Faulty occlusion, parafunctional habits, and inadequately contoured pontics, are common causes for fracture (2,11). Even normal occlusal forces can cause fractures, especially for long span FDPs (25,26). Thus, Interim restorations should demonstrate mechanical properties enough to support occlusal stresses, to maintain tooth position and to ensure clinical success (27)

Numerous interim materials are commercially available, Clinicians should know which material and manufacturing technique is suitable to use for each clinical situation, to reduce the risk of fracture. Whether CAD/CAM or conventional techniques are used, interim restorations should exhibit sufficient fracture strength for clinical success.

This study aimed to investigate the influence of fabrication technique on fracture resistance of 3-unit interim fixed dental prostheses (FDP) made by conventional and CAD/CAM techniques. The null hypothesis was that there will be no difference between the fracture resistance of the 2 groups.

MATERIAL AND METHODS

A mandibular right first molar was removed from a typodont model and the mandibular second premolar and molar were prepared according to the basic principles of crown preparation, with 1.5-mm reduction occlusally and a 1-mm chamfer finish line, 0.5 mm coronal to the cervical line, the convergence angle was 6 degrees .

A desktop scanner (Ceramill Map 400; AmannGirrbach, Koblach, Austria) was then used to scan the prepared model, after being sprayed with a thin layer of anti-reflective powder to enhance the scanning procedure. The standard tessellation language (STL) file of the scanned data was sent to a designing software (exocad DentalCAD version 2.4 plovdiv; exocad GmbH), the scanned model was then reduced to include the area of the abutment teeth and the pontic space, and a rectangular base was added to the model. The created modified model was then 3D printed as the master model which was then duplicated using epoxy resin material having an elastic modulus resembling that of dentin, to produce 32 identical working models, assigned randomly to 2 experimental groups (n=16/group according to the fabrication technique :

•Group MAN: manually fabricated poly methyl methacrylate PMMA.

•Group MIL: CAD/CAM fabricated poly methyl methacrylate PMMA.

A full anatomic 3-unit master FDP was designed on the CAD software and saved into STL file format, the connectors were set to be 4 mm occluso-gingivally and 3.25 mm bucco-lingually.

To standardize the fabrication process, The scanned master model and the designed FDP were used to create a digital mockup which was 3D-printed into a resin model, to serve as a template for the manual group.

For the manual group (Group MAN), A thin layer of petroleum jelly was applied on the working models to act as a separating medium. Interim FDPs were fabricated using compression molding technique, where addition silicone molds (Elite HD+; Zhermack, SpA, Italy, putty consistency and light body) were made over the template model. Chemically activated PMMA (Unifast III; GC Corp., Tokyo, Japan) was mixed with the recommended powder and liquid ratio and loaded into the molds from bottom to top to avoid entrapment of air bubbles. The filled impressions were fitted on their corresponding models. After complete setting, the interim FDPs were carefully removed from the molds, and acrylic burs were used to trim the excess material. Then specimens were polished with Sof-Lex discs (3M ESPE, St Paul, USA) and pumice .

For the CAD/CAM group (Group MIL) the designed master FDP was imported into the software (inLab CAM 20.1, dentsply sirona). 16 interim FDPs were fabricated in a 5-axis milling machine (sirona inlab MCX5; dentsply sirona), specimens were milled from Ceramill A-Temp

(AmannGirrbach, Koblach, Austria) PMMA resin blanks, following manufacturer's recommendations. after milling, FDPs were separated from the blank using an acrylic bur mounted on a straight handpiece and the supporting structures were removed.

All specimens were checked to detect air bubbles, defects or cracks. specimens were then cemented to their corresponding models using temporary cement (Cavex BV; Haarlem, Netherlands). The luting procedure was then continued by means of a customized apparatus that produces a constant load (5 kg) for 10 min. Excess cement was removed. FDPs cemented on their models were mounted and secured in a custom-made cyclic loading machine (Dental Biomaterial Department; Alexandria University; Alexandria, Egypt). A piston with three stainless-steel balls one for each unit (6 mm and 5 mm diameters for the molars, and the premolar respectively) was centrally positioned to load each unit of the prostheses vertically at the central fossa (Figure 3). 60,000 masticatory cycles of load up to 50 N and 1.7 Hz were exerted on the specimens, corresponding to 3 months of function (28)

Specimens were then submitted to static load testing, A stylus with 6 mm diameter ball made of steel, applied vertical load on the occlusal surface of the pontics in the FDPs. Each FDP was loaded along its long axis until fracture, in a universal testing machine (5ST, Tinius Olsen, England) at 1 mm/min crosshead speed (Figure 4). Failure load was recorded in newtons (N) using the software program (Tinius Olsen 5ST Horizon Software.(

STATISTICAL ANALYSIS

Visual inspection of data as well as normality was checked using Shapiro Wilk test and Q-Q plots. Comparisons of the fracture resistance between groups using independent t test. Significance was inferred at p value <0.05. Data analysis was done using IBM SPSS software for Macintosh (Version 28.0)

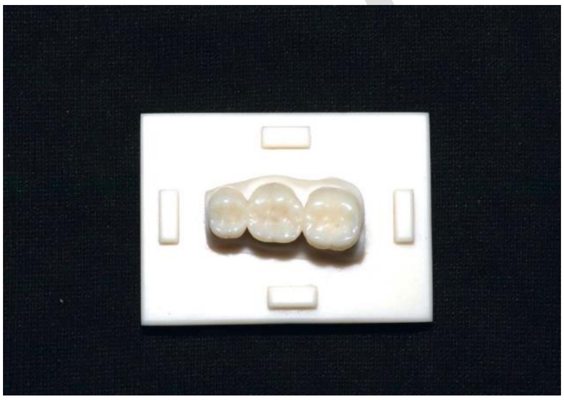

Figure 1. Conventional interim FDP.

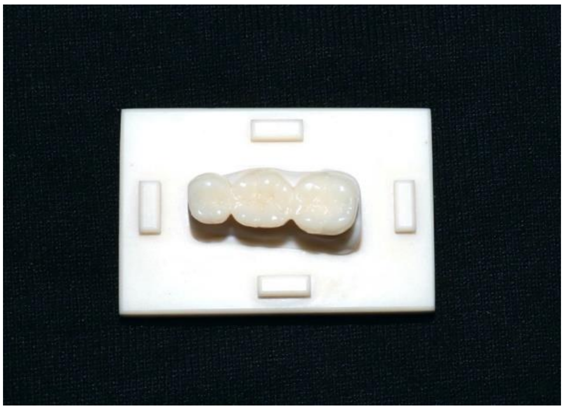

Figure 2. CAD/CAM interim FDP.

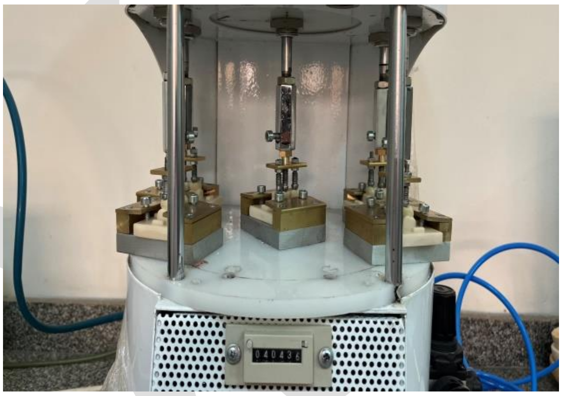

Figure 3. Cyclic loading of specimens.

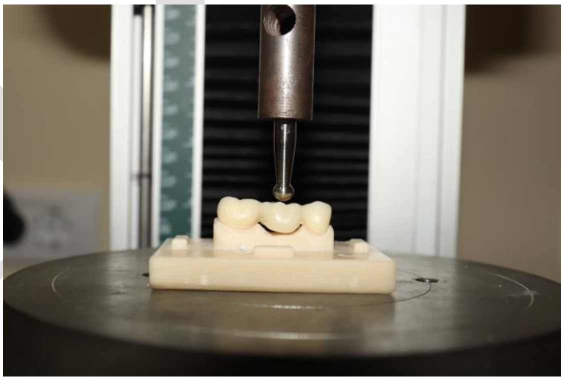

Figure 4. Fracture resistance test.

RESULTS

For the dynamic load testing, no failure was observed, and all specimens of both groups survived cyclic loading. For the static load test, Table 1. Shows the comparison of the mean±standard deviation, range and median of the fracture resistance of both groups. The mean value of fracture resistance for the CAD/CAM group was 1141.10 N, meanwhile, the mean value of fracture resistance for the manual group was 516.93 N. Independent t test revealed that CAD/CAM group's fracture resistance was higher significantly than manual's group (p <0.0001) showing that the fabrication technique significantly influences the fracture strength of interim restorations.

Table 1. Comparison between the two studied groups regarding the fracture resistance.

	CAD/CAM (n=16)	Manual (n= 16)
Mean ± SD	1141.10 ± 131.36	516.93 ± 62.96
Median (IQR)	1155.04 (199)	506.48 (99)
95% CI	(1071.10 –1211.10)	(483.38- 550.48)
Min - Max	816 – 1312	436 – 637
T test (P-value)	17.140 (<0.0001*)	

n: Number of specimens SD: standard deviation,
IQR: Inter- Quartile range CI: Confidence Interval
Min-Max: Minimum – Maximum
*Statistically significant at p value ≤ 0.05.

DISCUSSION

The purpose of this study was to investigate the influence of fabrication technique on the fracture resistance of 3-unit interim FDPs made by CAD/CAM milling and conventional techniques. Based on the results, the null hypothesis that there is no difference between different fabrication techniques on the fractures resistance was rejected.
To evaluate the fracture strength of the groups, specimens were cemented provisionally on their respective models to simulate the clinical conditions. The fracture strength of restorations is influenced by the abutments' elastic modulus (29), thus we used non rigid abutments made of epoxy resin. Non rigid abutments that have similar elastic modulus as dentin, behave similarly to the clinical conditions (30)

In the present study, all specimens of the 2 groups survived cyclic loading. The mean fracture resistance of the milled FDPs was 1141.1 N, while that of the manually fabricated ones was 516.93 N. The differences between the 2 groups were significant (p < 0.0001). This confirms that, when fabricating interim restorations, the fabrication method and precision both have a significant impact on the restoration's quality .

Although the main composition of CAD/CAM PMMA is not significantly different from the conventional one, its fracture strength was superior. Traditional methyl-methacrylates are monofunctional linear molecules with low molecular weight and exhibit low strength and rigidity (31). on the other hand, CAD/CAM blanks are made of highly crosslinked PMMA resins, Cross-linking improves the mechanical properties by raising the glass transition temperature (6)

Previous studies, in agreement with the present study, showed that CAD/CAM produced interim restorations that are significantly stronger than those produced manually (6,22,24,32–34). Pop et al. (35) also compared the fracture resistance of interim FDPs made by conventional and CAD/CAM PMMA, they found the milled restorations to be significantly higher than the conventionally fabricated ones .

In our study, the inferior mechanical properties of the conventional FDPs in comparison to the CAD/CAM ones can be attributed to the fabrication technique. Manual fabrication of interim restorations is influenced by the clinician's skills, proportioning, mixing procedures, and setting environment and time (22). Errors and defects such as incorporation of air bubbles can arise from manual proportioning and mixing, causing areas prone to crack propagation, negatively influencing the mechanical properties (14)

Digital technology minimizes these errors and produces standardized quality and uniformity, with no voids or porosities (6). CAD/CAM PMMA blanks are industrially polymerized in a highly controlled environment under high pressure and temperature, thus they have reached excellent physical and mechanical characteristics, and feature higher strength than the conventional materials (6 .(The normal masticatory forces were reported to be around 350 N in the molar region (36), while in patients with parafunctional habits, it may approach 900 N (37), since fracture is a common cause of failure for interim restorations (24), they should be able to sustain these stresses specially when they will be considered for longer periods of time (22). Materials tested in the study showed fracture strength values above average masticatory forces, however conventional PMMA might not be the material of choice for patients with bruxism or parafunctional habits. higher strength materials like those fabricated by CAD/CAM techniques represent an appropriate alternative for long span bridges and for long-term use.

Since this in vitro study doesn't replicate the oral environment, The fracture resistance values reported in the present study should be considered as relative values, however the results could be a strong predictor of clinical performance.
The study's limitations include, limited interim materials tested, not being able to replicate the oral conditions, using non-anatomical indenters for fatigue and fracture testing, and the absence of neighboring teeth.

CAD/CAM nowadays has made interim restorations easier to fabricate, and more resistant to fracture. However, many factors other than fracture resistance should be taken into consideration when selecting the suitable interim material for long term use, thus further invitro and clinical studies are required .

CONCLUSIONS

Within the limitations of the present study, it was concluded that the fracture resistance of interim restorations is influenced by the fabrication technique, CAD/CAM interim restorations show higher fracture resistance than manually fabricated ones and are more suitable for long-term use.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

FUNDING

The authors received no specific funding for this work.

REFERENCES

1. Shillingburg HT, Hobo S, Whitsett LD, Jacobi R, Brackett SE. Fundamentals of fixed prosthodontics. Chicago, IL, USA: Quintessence Publishing Company; 1997 Jan.
2. Gough M. A review of temporary crowns and bridges. Dental update. 1994 Jun 1;21:203-7.
3. Gegauff AG. Interim fixed restorations. Contemporary fixed prosthodontics. 2006:466-504.
4. Derbabian K, Marzola R, Donovan TE, Cho GC, Arcidiacono A. The science of communicating the art of esthetic dentistry. Part II: Diagnostic provisional restorations. J Esthet Restor Dent. 2000;12:238–47 .
5. Stiesch-Scholz M, Schulz K, Borchers L. In vitro fracture resistance of four-unit fiber-reinforced composite fixed partial dentures. Dental Materials. 2006 Apr 1;22:374-81.
6. Alt V, Hannig M, Wöstmann B, Balkenhol M. Fracture strength of temporary fixed partial dentures: CAD/CAM versus directly fabricated restorations. Dent Mater. 2011;27:339–47 .
7. Anusavice KJ. Mechanical properties of dental materials. Phillip's science of dental materials. 1996;457:493.
8. Christensen GJ. The fastest and best provisional restorations. The Journal of the American Dental Association. 2003 May 1;134:637-9.
9. Duke ES. Provisional restorative materials: a technology update. Compend Contin Educ Dent. 1999;20:497-500.
10. Burns DR, Beck DA, Nelson SK. A review of selected dental literature on contemporary provisional fixed prosthodontic treatment: report of the Committee on Research in Fixed Prosthodontics of the Academy of Fixed Prosthodontics. The Journal of prosthetic dentistry. 2003 Nov 1;90:474-97.
11. Burke FJT, Murray MC, Shortall ACC. Trends in indirect dentistry: 6. Provisional restorations, more than just a temporary. Dent Update. 2005;32 .
12. Wassell RW, St. George G, Ingledew RP, Steele JG. Crowns and other extra-coronal restorations: Provisional restorations. Br Dent J. 2002 Jun 15;192:619–30 .
13. Balkenhol M, Ferger P, Mautner MC, Wöstmann B. Provisional crown and fixed partial denture materials: mechanical properties and degree of conversion. Dental Materials. 2007 Dec 1;23:1574-83.
14. McLean JW. The failed restoration: causes of failure and how to prevent them. International dental journal. 1990 Dec 1;40:354-8.
15. Balkenhol M, Knapp M, Ferger P, Heun U, Wöstmann B. Correlation between polymerization shrinkage and marginal fit of temporary crowns. Dental materials. 2008 Nov 1;24:1575-84.
16. Thompson GA, Luo Q. Contribution of postpolymerization conditioning and storage environments to the mechanical properties of three interim restorative materials. The Journal of prosthetic dentistry. 2014 Sep 1;112:638-48.
17. Hamza TA, Johnston WM, Schricker SR. Effect of polyhedral silsesquioxane (POSS) on the flexural strength and color of interim materials. The Journal of prosthetic dentistry. 2014 Aug 1;112:228-34.
18. Poticny DJ, Klim J. CAD/CAM in-office technology: innovations after 25 years for predictable, esthetic outcomes. The journal of the American dental association. 2010 Jun 1;141:5S-9S.
19. Elagra MI, Rayyan MR, Alhomaidhi MM, Alanaziy AA, Alnefaie MO. Color stability and marginal integrity of interim crowns: An in vitro study. Eur J Dent. 2017;11:330–4 .
20. Gougaloff R, Stalley FC. Immediate placement and provisionalization of a dental implant utilizing the CEREC 3 CAD/CAM Protocol: a clinical case report. Journal of the California Dental Association. 2010 Mar 1;38:170-3.
21. Güth JF, e Silva JA, Edelhoff D. Enhancing the predictability of complex rehabilitation with a removable CAD/CAM-fabricated long-term provisional prosthesis: a clinical report. The Journal of prosthetic dentistry. 2012 Jan 1;107:1-6.
22. Rayyan MM, Aboushelib M, Sayed NM, Ibrahim A, Jimbo R. Comparison of interim restorations fabricated by CAD/CAM with those fabricated manually. J Prosthet Dent. 2015 Sep 1;114:414–9 .
23. Göncü Başaran E, Ayna E, Vallittu PK, Lassila LVJ. Load-bearing capacity of handmade and computer-aided design-computer-aided manufacturing-fabricated three-unit fixed dental prostheses of particulate filler composite. Acta Odontol Scand. 2011 May;69:144–50 .
24. Karaokutan I, Sayin G, Kara O. In vitro study of fracture strength of provisional crown materials. The journal of advanced prosthodontics. 2015 Feb 1;7:27-31.
25. Rosentritt M, Behr M, Lang R, Handel G. Flexural properties of prosthetic provisional polymers. The European Journal of Prosthodontics and Restorative Dentistry. 2004 Jun 1;12:75-9.
26. Koumjian JH, Nimmo A. Evaluation of fracture resistance of resins used for provisional restorations. The Journal of prosthetic dentistry. 1990 Dec 1;64:654-7.
27. Kim SH, Watts DC. In vitro study of edge-strength of provisional polymer-based crown and fixed partial denture materials. Dental Materials. 2007 Dec 1;23:1570-3.
28. Rosentritt M, Behr M, van der Zel JM, Feilzer AJ. Approach for valuating the influence of laboratory simulation. Dental materials. 2009 Mar 1;25:348-52.
29. Mahmood DJ, Linderoth EH, Vult Von Steyern P. The influence of support properties and complexity on fracture strength and fracture mode of all-ceramic fixed dental prostheses. Acta Odontologica Scandinavica. 2011 Jul 1;69:229-37.
30. Reymus M, Fabritius R, Keßler A, Hickel R, Edelhoff D, Stawarczyk B. Fracture load of 3D-printed fixed dental prostheses compared with milled and conventionally fabricated ones: the impact of resin material, build direction, post-curing, and

artificial aging—an in vitro study. Clin Oral Investig. 2019.

31. Cheng CJ, Lin CL, Shan YF. Multifactorial analysis of variables influencing the fracture strength of repair joints for provisional restorative materials using the statistically based Taguchi method. Journal of Dental Sciences. 2010 Jun 1;5:90-9 .
32. Stawarczyk B, Ender A, Trottmann A, Özcan M, Fischer J, Hämmerle CHF. Load-bearing capacity of CAD/CAM milled polymeric three-unit fixed dental prostheses: Effect of aging regimens. Clin Oral Investig. 2012 Dec;16:1669–77 .
33. Abdullah AO, Tsitrou EA, Pollington S. Comparative in vitro evaluation of CAD/CAM vs conventional provisional crowns. Journal of applied oral science. 2016 May;24:258-63.
34. Karaman T, Eser B, Altintas E, Atala MH. Evaluation of the effects of finish line type and width on the fracture strength of provisional crowns. Odontology. 2021 Jan 1;109:76–81 .
35. Pop DA, Malaescu R, Marsavina L, Hosszu T, Rotar R, Goguta L, Duma VF, Negrutiu ML, Sinescu C, Jivanescu A. Fracture Resistance of CAD/CAM Versus Traditional Interim Fixed Dental Prostheses. MATERIALE PLASTICE. 2018 Sep 1;55:361-3.
36. Pihut M, Wisniewska G, Majewski P, Gronkiewicz K, Majewski S. Measurement of occlusal forces in the therapy of functional disorders with the use of botulinum toxin type A. J Physiol Pharmacol. 2009 Dec 1;60:113-6.
37. Varga S, Spalj S, Lapter Varga M, Anic Milosevic S, Mestrovic S, Slaj M. Maximum voluntary molar bite force in subjects with normal occlusion. Eur J Orthod. 2011 Aug;33:427–33 .