ISSN: 2581-5989
PubMed - National Library of Medicine - ID: 101738774

International Journal of Dental Science and Innovative Research (IJDSIR)

IJDSIR : Dental Publication Service

Available Online at: www.ijdsir.com

Volume – 5, Issue – 3, June - 2022, Page No. : 525 - 537

A comparative evaluation of flexural strengths of carbon fiber and cobalt-chromium in bar retention systems for implant-retained prostheses - An in vitro study

[1]Dr. Leayol Thomas, Post graduate student, Department of Prosthodontics, crown & bridge and implantology, Mahe institute of Dental Sciences and hospital, Chalakkara, Mahe U.T of Puducherry, India.

[2]Dr. Prasad Aravind, MDS, Professor & Head, Department of Prosthodontics, crown & bridge and implantology, Mahe institute of Dental Sciences and hospital, Chalakkara, Mahe U.T of Puducherry, India.

[3]Dr. Abhinav Mohan, MDS, Reader, Department of Prosthodontics, crown & bridge and implantology, Mahe institute of Dental Sciences and hospital, Chalakkara, Mahe U.T of Puducherry, India.

[4]Dr. Cimmy, MDS, Senior lecture, Department of Prosthodontics, crown & bridge and implantology, Mahe institute of Dental Sciences and hospital, Chalakkara, Mahe U.T of Puducherry, India.

[5]Dr. Jayaprakash K, M. Sc, PhD. Reader, department of dental materials, Biomaterials and research center, Yenepoya dental college, yenepoya Deemed to be university, Mangalore, Karnataka, India.

Corresponding Author: Dr. Prasad Aravind, MDS, Professor & Head, Department of Prosthodontics, crown & bridge and implantology, Mahe institute of Dental Sciences and hospital, Chalakkara, Mahe U.T of Puducherry, India.

Citation of this Article: Dr. Leayol Thomas, Dr. Prasad Aravind, Dr. Abhinav Mohan, Dr. Cimmy, Dr. Jayaprakash K, “A comparative evaluation of flexural strengths of carbon fiber and cobalt-chromium in bar retention systems for implant-retained prostheses - An in vitro study”, IJDSIR- June - 2022, Vol. – 5, Issue - 3, P. No. 525 – 537.

Type of Publication: Original Research Article

Conflicts of Interest: Nil

Abstract

Purpose: To compare and evaluate the flexural strength of carbon fiber and cobalt-chromium in bar retention systems for implant-supported prostheses.

Method: A total of 16 samples were created where eight identical samples for carbon fiber testing and eight identical samples for Cr- Co testing. Testing of the flexural strength of both the bars (8 each of carbon fiber and CoCr) on the acrylic models using the universal testing machine (Tecsol, India) was carried out. The specifications of the testing are a Load cell of 20kN, a temperature of 27 °C, a speed of 5 mm/min, a pretension load of 200 gm, and a gauge length of 13 mm.

Results: Comparison of study parameters between carbon fiber and cobalt-chromium group showed that there was a statistically significant difference found in Young’s Modulus $p<0.001$ and in Modulus of Resilience $p<0.001$ favouring Cobalt chromium.

Conclusion: Cobalt-chromium bar showed the highest flexural strength which fractured at about 204N in comparison to the carbon fiber bar showed the lowest flexural strength fractured at a force of around 90N.

Keywords: Carbon fiber, Cobalt chromium, Implant retained prosthesis, flexural strength.

Introduction

Edentulism is a debilitating and irreversible condition and is described as the 'final marker of disease burden for oral health' [1]. Although the prevalence of complete tooth loss has declined over the last decade, edentulism remains a major condition worldwide, especially among older adults[2]. It was found to have a significant effect on residual ridge resorption[3], which leads to a reduction in the height of alveolar bone and the size of the denture bearing area. A conventional complete denture is the first-line treatment of choice for such patients[4].

Initially, the tooth is necessary for the development of alveolar bone where the stimulation of this bone is required to maintain its density and volume. A removable denture does not stimulate and maintain bone instead it accelerates bone loss. The load from mastication is transferred to the bone surface only, not the entire bone as a result blood supply is reduced, and total bone volume loss occurs[8]. Hence continuous residual ridge resorption causes many problems including reduced retention, instability of dentures, and soreness in the supporting mucosa owing to the reduced denture-bearing area.

Tooth-supported or implant-supported overdentures are a preferable alternative to treatment with conventional complete dentures, the main advantages are decreased resorption of the residual ridges; psychological benefits for the patients, and maintenance of masticatory efficiency.

The use of dental implants to provide support for prostheses offers a multitude of advantages compared with the use of removable soft tissue-borne prostheses. A Bone trabeculae and density increase when the dental implant is inserted and functioning[9]. Implant-supported overdenture prostheses provide enhanced esthetics, phonetics, retention, and stability than the conventional complete denture.

The mandibular implant-retained overdenture has been investigated only with longitudinal studies since 1987. Van Steenberg he et al[10] and Mericske-Stern et al[11] concluded that stabilization of lower dentures with two intermorainal implants has provided reliable and predictable treatment outcomes. It is regarded as the minimum standard of care for edentulous patients. The prognosis of the prosthesis includes two important factors: (1) Retention and (2) stress distribution among others.

The retention of implant-retained and/or implant-supported full-arch prosthesis can be accomplished by either splinting the implants or leaving them unpainted. Implants splinted together with a bar prevent implant micromotion and axial rotation[15].

Recent improvements in composite materials have made it possible to fabricate metal-free prostheses. Carbon fibers are filaments made of 99.9% chemically pure carbon with a 5–10 μm diameter. They provide high stiffness, lightweight, low density, low coefficient of thermal expansion, low abrasion, good electrical conductivity and vibration damping, biological compatibility, chemical inertness (except in strongly oxidizing environments or when in contact with certain molten metals), elasticity to failure at normal temperature, high fracture strength, high fatigue and creep resistance [12–14]. These characteristics make Carbon Fiber Reinforced Composites (CFRC) appear excellent for the fabrication of any metal-free prosthesis.

Aim

This study aims to compare and evaluate the flexural strength of carbon fiber and cobaltchromium in bar retention systems for implant-supported prostheses.

Objectives

1. To evaluate the flexural strength of carbon fiber bar
2. To evaluate the flexural strength of the cobalt-chromium bar
3. To compare the flexural strengths of carbon fiber and cobalt-chromium bars.
4. To analyze the labial flaring of the maxillary anterior segment during intrusion under different loads.

Materials and methods

Materials

1. Edentulous mandibular model (DPI ® Heat Cure, DPI, Mumbai, Maharashtra, India.
2. root-form non-hexed implants 3.5x10mm (Dentium implant system, Seoul, Korea)
3. Castable abutment (Dentium implant system, Seoul, Korea)
4. Stock abutments (Dentium implant system, Seoul, Korea
5. Pattern resin (GC Pattern Resin, GC Corporation, Japan) 6. Carbon fiber (Ruthenium fibra)
7. Addition silicone putty material (flexed putty type ployvenylsiloxane)
8. Clear splint biocryl 0.1 mm sheet (Bio star)

Equipment

1. Casting machine (Fornex T BEGO)
2. Acryliser (Acrydent, VILMAN, India)
3. Surveyor (marathon -103)
4. Milling machine (Paraskop M Bego)
5. Weighing machine
6. Pressure molding machine (Bio star)
7. Sandblasting machine (Easy blast Bego Bremer goldschia Gurel)
8. Vacuum sealer machine (JIG's MART)
9. Universal testing machine (TESCOL, INDIA)

Methodology

Sample size

A total of 16 samples were created as shown in (figure 1). Eight identical experimental mandibular bar retention system samples for carbon fiber testing were made by splinting the implants with pattern resin and putty index technique. The eight identical bar retention system samples were waxed up to the dummy implants using preformed wax patterns and inlay wax for Cr-Co testing.

Figure 1: heat cure acrylic model fabricated by duplication of mandibular study stone model.

Fabrication of study models

The experimental acrylic models were constructed by duplication of the commercially available mandibular edentulous stone model (without undercuts) into clear heat-cured polymerized polymethyl methacrylate resin (DPI ® Heat Cure, DPI, Mumbai, Maharashtra, India).

Two root-form dummy implants, 3.5 mm in diameter and 10 mm in length (Dentium implant system, Seoul, Korea), were placed bilaterally in the canine regions at positions B and D. They were placed parallel to each other, equidistant from the midline and at the same height. The inter implant distance was 12 mm.

The drilling for implants sites was done by using a milling machine (figure 2). Surveyor was used to access the parallelism of the implants. The dummy implants were secured to the model using chemically activated denture base resin.

Figure 2: access holes were made for placement of implant.

Fabrication of Co-Cr Bar

A plastic castable abutment with a metal base (diameter 3.5 and length 10) was attached to the dummy implants. The abutments were waxed up to the preformed bar wax pattern which was used to form the Co-Cr-cast bar (diameter-3.5mm, width-12mm, height-4mm) connecting the two abutments with desired dimensions. A 2 mm clearance space was maintained between the bar and ridge. The models were invested, cast in chromium-cobalt alloy and the bars were trimmed and polished. Fit and marginal integrity will be evaluated on the models (Figure 3).

Figure 3: the final study model with cobalt chromium bar.

Fabrication of Carbon Fiber Bar

1. First the external surface of the titanium abutments was subjected to sandblasting with aluminium oxide particles. (110 micrometres/150 mesh, Rin fret, Germany) after protecting the abutment base and the screw access hole (Figure 4).

Figure 4: sandblasted abutments

2. A mock-up for the bar was made using pattern resin, in this way we supported our assembly and obtained the ideal thicknesses for the abutments. A vestibular and lingual mask of the bar was made with flexed addition silicone (Figure 5).

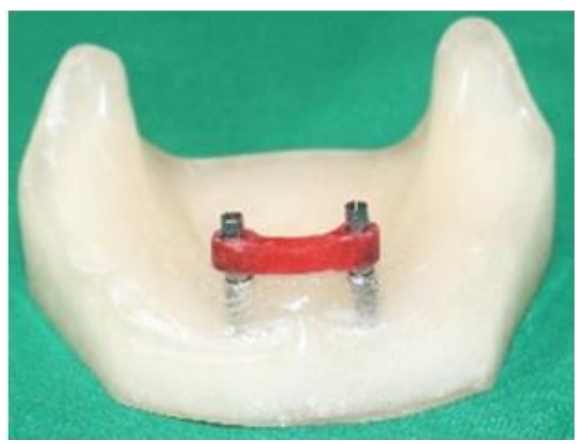


Figure 5: mock-up of carbon fibre bar made using pattern resin

3. The abutments were detached from the resin by making vestibular reference notches with a handpiece.

4. A 9 grams of ruthenium base resin was mixed with 3 grams of ruthenium catalyst resin. The ratio must always be 3: 1.

5. The activated ruthenium resin is poured on the UHM fabric and was spread with the spatula supplied making sure it soaks all the fabric. With the same spatula, the excess of the ruthenium resin was removed both on the fabric and on the plastic sheet.

6. The taped edges were cut so that the impregnated UHM fabric does not fray anymore.

7. The template was positioned on the impregnated fabric and rectangular cut-outs were made with the scissor as large as our paper template. They were overlapped over one another by doing so we are changing the inclination of the fibers by 10–15 degrees. This operation is called MANUAL LAMINATION (Figure 6). For fabric, a minimum number of sheets to laminate is 13 in number. With the roller, any entrained air was removed.

8. The paper template was overlapped on the laminated sheets and was cut into the shape of our bar.

9. The carbonia powder was added in excess to the activated ruthenium resin, this was, the powder we obtained from a previous finishing, the mixture obtained was brushed, gel coat, on the abutments.

10.The horseshoe made with laminated UHM fabric was opened with a pointed instrument near the abutment and was made fit (Figure 7).

11.The fabric leftover from the cut of the laminated fabric was transferred into coarse pieces. These fibers were placed on top of the laminated sheets to increase the volume of our bar.

Figure 7: the laminated UHM fabric was adapted to the abutments.

12.The bar and the model were placed in an embossed bag for food vacuum. The vaccumization was done and in this phase, we help each other with the main ones to better adapt the bar to the model (Figure 8). The sealed bag was placed in water and was brought from room temperature to 80 degrees where it was being kept for 2 hours. The cooking cycle is 2 and a half hours.

Figure 8: The entire model with the bar is vacuum sealed in vacuum sealing machine

13.After firing once it has cooled down, the bar was removed from the model. We can easily remove the thermoformed disc and the finishing of the bar was done with the cutters that we usually use. With the initial templates, we adapted the bar to its original shape.

14.The final product is finished and polished (Figure 9)

Figure 9: finished and polished carbon fibre bar

Testing the Flexural Strength

Testing of the flexural strength of both the bars (8 each of carbon fiber and Co-Cr) on the acrylic models using the universal testing machine (Tecsol, India) was carried out. The specifications of the testing are: Load cell of 20kN was selected after load calibration is carried out, at the temperature of 27 °C, speed of 5 mm/min, pretension load of 200 gm, and a gauge length of 13 mm.

Figure11: cobalt chromium fractured at 204N

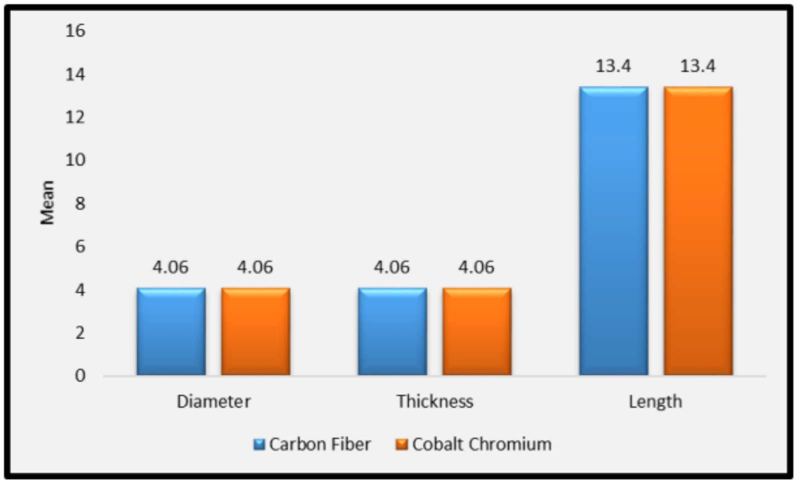
Figure 12: carbon fibre fractured at 90N.

Results

Statistical analysis for the strength of bar materials was performed, and the mean value with its standard deviation was calculated for each material. The obtained data were coded and entered into a Microsoft Excel sheet. Data were analyzed using the statistical package for social sciences (SPSS) version 22.0 (SPSS Inc, Chicago IL). Mean values of the experimental groups were compared using a T-test, at a 5% level of significance ($p \leq 0.05$).

Variable	Group	n	Mean	SD	t value	p-value
Diameter	Carbon Fiber	8	4.06	00	-	-
	Cobalt-Chromium	8	4.06	00		
Thickness	Carbon Fiber	8	5.00	00	-	-
	Cobalt-Chromium	8	5.00	00		
Length	Carbon Fiber	8	13.40	00	-	-
	Cobalt-Chromium	8	13.40	00		

Table 1: Comparison of study parameters between carbon fiber and cobalt-chromium group.

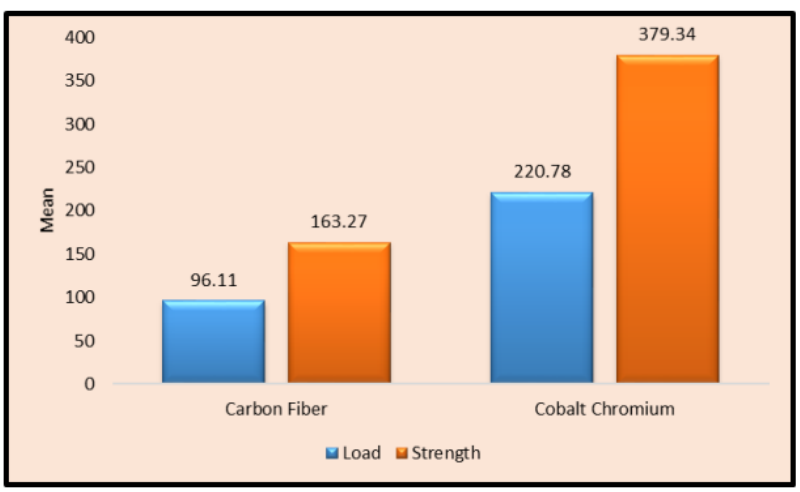


Graph 1: Comparison of study parameters between carbon fibre and cobalt chromium group

A comparison of the Diameter, thickness, and length of the carbon fiber and cobalt-chromium groups revealed that they are comparable and homogenous.

Variable	Group	N	Mean	SD	t value	p-value
Load	Carbon Fiber	8	96.11	3.50	50.27	0.000
	Cobalt-Chromium	8	220.78	6.08		
Strength	Carbon Fiber	8	163.27	7.68	57.57	0.000
	Cobalt-Chromium	8	379.34	7.32		

Table 2: Comparison of Load and Strength between carbon fiber and cobalt-chromium group (Significant $p<0.001$)

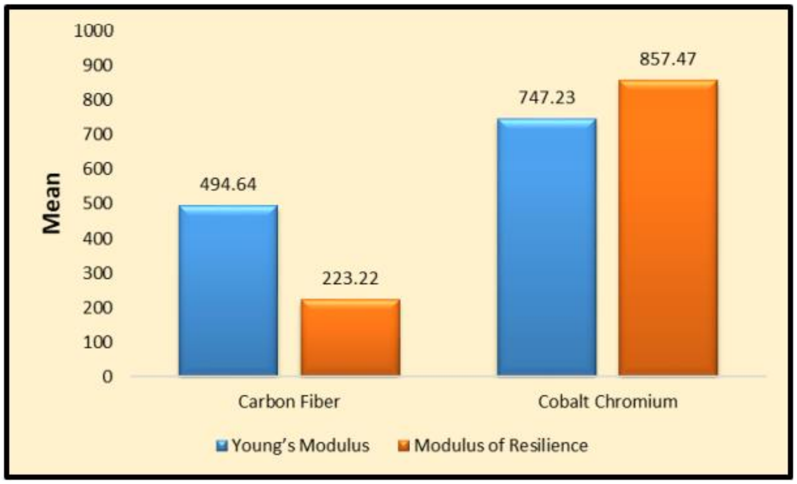


Graph 2. Comparison of Load and Strength between carbon fiber and cobalt-chromium group

A comparison of study parameters between carbon fiber and cobalt-chromium group showed that there was a statistically significant difference found in load p<0.001 and in strength p<0.001 favouring Cobalt chromium.

Variable	Group	N	Mean	SD	t value	p-value
Young's Modulus	Carbon Fiber	8	494.64	59.23	4.85	0.000
	Cobalt-Chromium	8	747.23	134.70		
Modulus of Resilience	Carbon Fiber	8	223.22	54.98	32.48	0.000
	Cobalt-Chromium	8	857.47	5.11		

Table 3: Comparison of Young's Modulus and Modulus of Resilience between carbon fiber and cobalt-chromium group (Significant p<0.001)



Graph 3: Comparison of Young's Modulus and Modulus of Resilience between carbon fiber and cobalt-chromium group.

The results obtained from this study

1. In in vitro experiments, the flexural strength of the cobalt-chromium bar was found to be significantly higher than the flexural strength of the carbon fiber bar.
2. Comparing the mean flexural strength of each group, the T-test showed significantly different flexural strengths among the groups. Comparison of study parameters between carbon fiber and cobalt-chromium group showed that there was a statistically significant difference found in Young's Modulus p<0.001 and in Modulus of Resilience p<0.001 favouring Cobalt chromium.
3. The 16 samples were loaded in the universal load frame at a right angle to the specimens. After the appearance of a visual sign of fracture, the loading was stopped. The force that the specimen withstands till a fracture occurred was recorded as the peak fracture,
4. According to the findings, it was found cobalt-chromium bar showed the highest flexural strength which fractured at about 204N (Figure 11) in comparison to the carbon fiber bar showed the lowest flexural strength which fractured at a force of around 90N (Figure 12), even though carbon fiber showed the lowest value it can be used for the implant-supported overdenture bar as it fractured within the normal range of the physiologic biting force of an individual which was 77N. The cobalt-chromium failed at screw level whereas the carbon fiber failed at bar level.

Discussion

Teeth may be lost because of trauma, caries, periodontal diseases, congenital defects, and iatrogenic treatment.

Tooth loss has a negative impact on masticatory function, aesthetics [16].

Douglas Allen Atwood et al stated the vertical bone loss of the anterior part of the ridge in 19 years was 3mm in maxillae and 14.5 mm in the mandible. As a result of this, the retention and stability of conventional complete dentures are more of a concern in the mandible than in the maxilla. This is primarily attributed to the reduced surface area for support and retention in the mandibular arch[17].

Retention is a major concern in an implant-supported overdenture. The bar framework material, loading angle, the number of implants as well as the design of the bars are important factors that influenced the stress in the implants, bars, and bone bed. Many factors could influence the displacement of the overdenture. Kamei et al. (2018)[18] concluded in their study that the displacement was lower in an overdenture supported with four than with two implants. Zhang et al. (2018)[19] showed in their study that more than two implants had a lower displacement of the overdenture. Moreover, the attachment system could influence the displacement in the overdenture. Manju and Sree Lal (2013)[19] investigated in their study a mandibular implant supported overdenture in comparison to ball, bar, and magnetic attachments. They concluded that the lowest displacement of the overdenture was in the simulations with the bar/clip attachment. Francesco Pera et al 2016 concluded that the carbon fiber framework presented less marginal bone loss around the implants and a better implant survival rate during the observation period of 2 years. he also stated that Carbon fiber-supported prostheses presented a reduced implant failure (CSR: 100%) concerning implants rehabilitated with metal ones (CSR: 93,9%)[20]. Menini M et al in 2015 stated that similar to metal frameworks, the high stiffness of CFRC helps distribute the occlusal load over all the supporting implants. Differences in CSR and bone resorption between metal and carbon fiber framework prostheses could depend on the different elastic properties of carbon fiber compared to metal. carbon fiber bars can distribute the applied forces evenly through the entire prosthetic framework, providing high resistance, rigidity (modulus of elasticity > 60000 MPa), strength, and thermal stability.

The polymeric matrix binds the fibers together transferring the load among them and guarantees the protection of the fiber against chemical attack and mechanical damage. On the other hand, it is important to underline that Menini et al. demonstrated that manufacturing technique strongly affects the material's mechanical characteristics. For this reason, they suggested the development of a strict protocol for the fabrication of these devices and specific training for dental technicians[21].

Carbon fiber-reinforced composite devices can be produced following many different techniques mainly developed in the aerospace and automotive environments. The final properties of the items created by adopting CFRC may show surprising differences due to the various technical procedures followed to realize them. Moreover, in contrast with metal alloy, which is an anisotropic, homogeneous material, CFRC is an anisotropic and non-homogeneous material. It is therefore extremely important to consider during manufacturing that mechanical, electrical, and thermal properties are different, along with the various directions of the material. In CFRC best properties are provided along the fibber's axis direction (thanks to covalent bonds between carbon atoms), while they are usually very low in a direction perpendicular to them. The polymer matrix provides very low mechanical properties but vibration damping and fiber coating. The mechanical properties of the final devices are dependent upon the fiber direction axis.

CFRC devices are usually created by superimposing several carbon fiber layers, normally 0.1 mm thick, until the final desired dimension is reached. Using monodirectional layers, known as “prepregs”, because the resin is already present in the layer, extremely high mechanical performance devices can be realized. Indeed, being highly directional materials, the stacking sequence of the superimposed layers should be aligned along with the directions of the forces acting on the material. This task can be easily achieved when dealing with a regularly shaped [18] device, but it could be a very challenging goal with a non-regular, rounded, non-symmetric shape like a dental arch.

Moreover, it's to be underlined that the devices created with this method show an X-Y range of fiber disposal direction, while no fibers are placed along the Z-axis. this suggests that any curvature and deformation may provide stresses unmanageable by the structure itself, resulting in delamination. To skip these problems different layer typologies, called “fabric”, are adopted when it's not necessary to get the highest mechanical properties.

Fabric CFRC layers are created with perpendicularly crossed fibers following the identical patterns adopted in tissue industries. In this way, fibers are not any longer aligned in one single direction but are crossed at their disposal. As a consequence, the mechanical behaviour of the layers is no longer defined by one direction but the fabric is “more isotropic” in its performance. This also allows non-specialist, non-aerospace technicians to successfully apply CFRC in their manufacturing. Indeed, the ultimate device properties are greatly plagued by the material layers superimposing technique. Hand procedure is generally adopted when final shapes are complicated, rounded, or unique in their creation and automatic large-scale procedures don't seem to be recommended. Fabric layers are usually provided by the suppliers with none resin. this is often essential in biomedical applications thanks to the requirement to adopt specific biocompatible resins, freed from non-biocompatible solvents or chemical compounds normally found in aerospace applications. Fabrics are therefore superimposed by alternating resin deposition. during this phase, it's extremely important to ensure that resin penetrates among the layers and inside the patterns. Resin gaps will be assumed as mechanical weaknesses. In bio applications, this could also cause potential bacteria pockets, where infections or other medical-related problems may arise. it's therefore mandatory to make a really compact, robust, and pore-free material. Many techniques are available to realize this goal, mainly associated with the precise skills of the technicians engaged in these creations. As demonstrated within the present paper, the ultimate results is also quite different even when the identical fibers and resins are applied by different technicians. Nowadays carbon fibers are successfully employed in Dentistry to provide root posts, increase the resistance of mobile prostheses, and build dental instruments. The findings of this research suggest that carbon fibers is also also used as reinforcements of frameworks for fixed implant-supported restorations. The CFRC samples exhibited optimal biocompatibility and mechanical properties adore gold alloy. carbon fiber is very biocompatible and shows superior mechanical properties.

In a multiunit prosthesis, a stiff substructure rigidly splinting the implants would be the most effective choice to evenly distribute loads. The shock absorption capacity of more resilient restorative materials like resin might be used at the extent of occlusal surface in association with a stiff substructure. Materials with relatively low young modulus, produce a biomechanical improvement by transferring less tension to the supporting structures. Elastic prosthodontic materials (such as acrylic resin) are demonstrated to own a shock absorption capacity as opposition stiffer materials (such as zirconia and dental ceramics) when simulating single crowns. Finite Element Analysis (FEA) suggested that a rigid framework is biomechanically advantageous compared to a full acrylic prosthesis. Testing prostheses supplied with a metal framework stress transmitted to implants, prosthesis, and peri implant-bone were more homogeneous compared to full-acrylic prostheses. the strain was partly distributed to contralateral implants reducing the utmost values of stress recorded next to the load application point. The carbon fiber framework induced a load distribution almost like the metal framework. this can be because of the upper stiffness of metal and CFRC frameworks compared to acrylic. employing a CFRC framework compression applied perpendicularly to the surface of the denture is additionally perpendicular to the axis of the fibers. However, similar yield strengths were recorded for the denture supplied with a metal framework and therefore the one supplied with a CFRC framework. Compressive and flexural strength is that the most vital aspect for the choice of appropriate bar material because the stronger the fabric better is its ability to resist deformation and fracture and even load distribution. Flexural strength is an indirect measure of durability and may be determined from a third-point loading and center-point loading test. In this study, the loading force was uniaxial, with 80-200N within the mid-region of the bar, this corresponds to the average biting force which is 77 N of force[22,23]. during this study, the best values were found for the cobaltchromium bar which fractured at about 204N as compared to the carbon fiber bar which fractured at a force of around 90N. the cobalt-chromium bar failed at the screw level and therefore the carbon fiber failed at the bar level. Here the comparison of flexural strength between carbon fiber and cobalt-chromium bar has finished a T-test. The test result demonstrates that cobalt-chromium (control group) showed the very best flexural strength value of 324±383Mpa whereas carbon fiber showed all-time low flexural strength value of 154.4±167.2Mpa. Comparison of study parameters between carbon fiber and cobalt-chromium group showed that there was a statistically significant difference found in Young's Modulus $p<0.001$ and in Modulus of Resilience $p<0.001$ favouring Cobalt chromium. while carbon fiber showed the bottom value it may be used for the implant-supported overdenture bar because it fractured within the traditional range of the physiologic biting force of a private. this study was an in vitro study and so has inherent limitations. it had been not allotted on vital bovine and/or on a procaine bone block or in vivo. Fatigue occurrence would be observed in bar material under continuous forces within the mouth and there may well be fractures under lower forces. additionally, the change of temperature within the mouth could also affect flexural strength. Studies considering these issues will show the effect of conditions on the mouth in a very better way. the current study was conducted in a perfect laboratory environment which cannot be the expected scenario within the clinical situation. Therefore, these materials should be tested clinically to compare and evaluate their performance under similar loads.

Conclusion

From the above study, it was found that cobalt-chromium showed the highest flexural strength of carbon fiber. The comparative parameters were within the statistically significant range ($p \leq 0.001$). The modulus of elasticity of carbon fiber ranges from (200– to 220 GPA). In our study even though the carbon fractured at the lowest load, it was within the physiologic limit of the masticatory load. It was under debate that the mechanical properties of carbon fiber rely on the method of fabrication. it needs a well-trained technician to achieve its maximal strength. Hence Frameworks made of CFRC might be a viable alternative to traditional metal for an implantsupported overdenture bar in implant prosthodontics, providing similar stiffness and rigidity and optimal biocompatibility. The development of a protocol for the fabrication of these devices and specific training for dental technicians is recommended to achieve satisfactory results.

References

1. Cunha-Cruz J, Hujoel PP, Nadanovsky P. Secular trends in socio-economic disparities in edentulism: USA, 1972–2001. Journal of Dental Research. 2007;86(2):131–136. [22]
2. Douglass CW, Shih A, Ostry L. Will there be a need for complete dentures in the United States in 2020? Journal of Prosthetic Dentistry. 2002;87(1):5
3. Allen PF, McMillan AS. A review of the functional and psychosocial outcomes of edentulousness treated with complete replacement dentures. Journal of the Canadian Dental Association. 2003;69(10): p. 662.
4. Tallgren A. The continuing reduction of the residual alveolar ridges in complete denture wearers: a mixed-longitudinal study covering 25 years. The Journal of Prosthetic Dentistry. 1972;27(2):120–132.
5. Divaris K, Ntounis A, Marinis A, Polyzois G, Polychronopoulos A. Loss of natural dentition: multi-level effects among a geriatric population. Gerodontology. 2012;29(2):192–199.
6. Tallgren A, Lang BR, Miller RL. A longitudinal study of soft-tissue profile changes in patients receiving immediate complete dentures. The International Journal of Prosthodontics. 1991;4(1):9–16.
7. Carlsson GE. Clinical morbidity and sequelae of treatment with complete dentures. Journal of Prosthetic Dentistry. 1998;79(1):17–23.
8. Mericske-Stern R, stein Lin Schaffner T, Marti P, Geering AH. Peri-implant mucosal aspects of ITI implants supporting overdentures. A five-year longitudinal study. Clin Oral Implants Res 1994; 5:9-18.

3. Jemt T, Chai J, Harnett J, Heath MR, Hutton JE, Johns RB, et al. A 5-year

9. Dental implant prosthetics, Carl E Misch,2ndedition prospective multicentre follow-up report on overdentures supported by osseointegrated implants. Int J Oral Maxillofac Implants 1996; 11:291-8. [23]
10. The edentulous predicament. i: a prospective study of the effectiveness of implantsupported fixed prostheses. The journal of American dental association volume 127, issue 1, January 1996, Pages 59-65.
11. Masticatory movements and the resulting force archives of oral biology, volume 12, issue 2, February 1967, Pages 195-202.
12. Masticatory movements and the resulting force archives of oral biology, volume 12, issue 2, February 1967, Pages 195-202.
13. Smith D: the mobility of artificial dentures during communication, J Prosthet Dent 13:462- 468,1963
14. Lundqvist S, Harald son T: occlusal perception of thickness in patient with bridges on osseointegrated oral implants, Scand. J Dent Res 92:88,1984.
15. Van Kampen F, Cune M, van der Bilt A, Bosman F (2003) Retention and postinsertion maintenance of bar-

clip, ball and magnet attachments in mandibular implant overdenture treatment: an in vivo comparison after 3 months of function. Clin Oral Implants Res 14(6): 720-726.

16. OOSTERHAVEN S. P., WESTERT G. P., SCHAUB R. M.: Perception and significance of dental appearance: the case of missing teeth. Community Dent. Oral Epidemiol. 17: 123– 126, 1989

17. Clinical, cephalometric, and densitometric study of reduction of residual ridges Douglas A. Atwood, M.D., D.M.D., * and Willard A. Coy, D.M.D.** Haruard School of Dental Medicine, Boston, Mass. volume 26 issue 3 September 1971, Pages 280-295

18. Selden AI, Persson B, Born Berger - Dankvardt SI, et al. Exposure to cobalt chromium dust and lung disorders in dental technicians. Thorax. 1995;50: 769–772.

19. Biological and mechanical characterization of carbon fiber frameworks for dental implant applications Maria Manini a, Paolo Pesce a, ⁎, Francesco Pera a, Fabrizio Barberis b, [24] Alberto Lagazzo b, Ludovica Bertola b, Paolo Pera a Implant and Prosthetic Dentistry Unit, University of Genoa, Ospedale S. Martino (pad. 4), L. Rosanna Benzi 10, 16132 Genoa, Italy b Department of Civil, Chemical and Environmental Engineering, University of Genoa, Via Mont allegro, 1-16145 Genoa, Italy. J med science volume 10-part 1 January 2017, Pages 646-655

20. Kamei K, Gonda T, Takahashi T, Maeda Y. Mechanical study of optimal implant position for maxillary implant-supported overdentures using three-dimensional simulation software. Int J Prosthodont (IJP) 2018; 31:619–26.

21. Zhang X, Liu W, Qing H, Pei X, Chen J, Wang J. Effect of implant number on the movement of mandibular implant-supported overdentures under biting force: an in-vitro study. Quintessence Int 2018; 49:709–17.

22. Carbon fiber vs. metal framework in full-arch immediate loading rehabilitations of the maxilla – a cohort clinical study Authors: Francesco Pera.2016

23. Menini M, Pesce P, Bevilacqua M, Pera F, Teal do T, Barberis F, Pera P. Effect of framework in an implant-supported full-arch fixed prosthesis: 3D finite element analysis. Int J Prosthodont 2015; 28:627-630