Effect Of Hyperbaric Pressure in Diving Simulation To Fracture Strength And Fracture Pattern On Different Post System of Endodontically Treated Teeth: An in-vitro study

Debora Natalyna1, Trimurni Abidin2, Wandania Farahanny2

1. Resident of Specialist Program of Conservative Dentistry, Department of Conservative Dentistry, Faculty of Dentistry, Universitas Sumatera Utara, Padang Bulan,

Medan, Indonesia

2. Department of Conservative Dentistry,

Faculty of Dentistry, Universitas Sumatera Utara, Padang Bulan,

Medan, Indonesia

1,2 Department of Conservative Dentistry,

Faculty of Dentistry, Universitas Sumatera Utara, Padang Bulan,

Medan, Indonesia

Jl. Alumni No.2. Kampus USU. Medan 20155

Corresponding author:

Trimurni Abidin

Department of Conservative Dentistry,

Faculty of Dentistry, Universitas Sumatera Utara, Padang Bulan,

Medan, Indonesia

Jl. Alumni No.2. Kampus USU. Medan 20155

Email: tri.murni@usu.ac.id

ABSTRACT

Introduction: Hyperbaric pressure is a condition of environmental pressure that is greater than 1 atmosphere experienced by divers. Hyperbaric pressure can damage the teeth, as well as restorations. The use of fiber posts in post-endodontic restorations has limitations in adapting the shape of the post to the root canal which can cause the thicker of resin cement so that the risk of void formation will be greater. This study aims to evaluate the effect of hyperbaric pressure on fracture resistance and fracture patterns in different post systems.

Materials and methods: Forty extracted single root mandibular premolars were decoronated 2 mm above the CEJ and endodontic treatment was done. The teeth were divided into four groups: SFP1 (Single prefabricated fiber post with 1 ATA air pressure), SFP4 (Single prefabricated fiber post with 4 ATA air pressure), AFP4 (Anatomic fiber post with 1

ATA air pressure), AFP4 (Anatomic fiber post with 4 ATA air pressure). All posts were cemented with dual cure resin cement with total etch adhesive system. The core and crown were made clinically with direct composite resin and then carried out a thermoycling process for 200 cycles. Groups B and D was put in to hyperbaric chamber with pressure changes from 1 ATA to 4 ATA for 24 cycles. The fracture test was performed using a Universal Testing Machine (UTM) with static load was applied to the axial tooth at a speed of 0.5 mm/min until fracture occurred and the fracture pattern was observed. The data obtained was tested with one-way analysis of variance (ANOVA), while for fracture patterns with categorical data were tested using Kruskal Wallis Test.

Results: Regardless of the pressure, anatomic post (AFP1) achieved the highest fracture strength 668.82 N ± 90.84 compare with single fiber post (SFP1) 541.30 N ± 79.50 ($p < 0.01$). The fracture strength were significantly lower after they were subjected to the pressure cycles which is 482.69 N ± 81.57 for anatomic post (AFP 4)and 428.23 N ± 68.34 ($p < 0.05$) for single fiber post (SFP4). No statistically significant differences ($p = 0.958$) were found in fracture pattern between all groups and 90% of the fracture was repairable.

Conclusion: The results showed that hyperbaric pressure has an effect on fracture resistance in different post endodontic post systems. However, hyperbaric pressure has no effect on fracture patterns in different post endodontic post systems.

Keywords: anatomic fiber post, fracture resistance, hyperbaric pressure.

INTRODUCTION

Endodontic tooth restoration has an important role in determining the success rate of root canal treatment. Post-endodontic teeth tend to be weaker than intact teeth due to the large loss of tooth structure, decreased flexural strength, changes in collagen cross-linking ability and reduced water content due to tooth dehydration. When most of the coronal structure of an endodontically treated tooth is lost due to caries or root canal treatment, the use of a post and core system should be considered1. The main purpose of using dowels is to add retention to the core that will support the crown. Recently, the use of fiber posts is more recommended than metal posts because fiber posts have many advantages. These posts are easy to manipulate, have good mechanical properties, low toxicity and have a modulus of elasticity that is more similar to that of dentin2 resulting in a more even distribution of stress along the root and can reduce the incidence of catastrophic failure3,4. Some other very beneficial properties of fiber post are high impact resistance, ability to reduce vibration, shock absorption and increase fatigue resistance2,5. Fiber post, resin cement and dentin have almost the same modulus of elasticity and all three bind adhesively to form a monoblock system so as to increase the seal strength in the coronal and apical sections6. The monoblock system will distribute the applied load homogeneously and reduce the pressure on the masticatory function so that it is very beneficial and increases the success of the restoration 6,7. Clinical evaluation of fiber post and core restorations has been reported to be more effective with a high success rate and a reduction in root fracture failure8,9,10.

Prefabricated fiber post, which is a factory-made post, does not always adapt to the shape and diameter of the root canal. If the adaptation is not good, the resin cement will become thick so that it can increase the polymerization pressure of the interfacial surface between the dentin-cement and cement-post which will form air bubbles and adhesion defects. In an effort to improve the adaptation of glass fiber posts in the case of wide root canals, one of the proposed techniques is the manufacture of anatomically adjusted posts. This technique will adapt the shape of the prefabricated fiber post to the root canal by performing root canal impressions or by relining the fiber post using a composite resin. Increasing the adaptation of the post to the root canal wall will allow the use of a thin layer of resin cement thereby providing favorable conditions for retaining the post and reducing the risk of adhesion failure11. Several studies have shown that anatomic posts have higher fracture resistance than other fiber post systems and have better retention to the canal wall than single fiber prefabricated posts12,13,14.

Hyperbaric pressure is a condition of environmental pressure outside the body that is greater than 1 atmosphere. The pressure will increase in direct proportion to the depth of the dive. Air pressure increases by 1 ATA for every 10 m increase in depth15. Hyperbaric pressure has been recognized as initiating damage to the restored tooth, causing fracture of the restoration tooth and reduced retention of prosthetic devices16,17. Barotrauma in diver teeth can manifest as tooth fracture, restoration fracture and reduced restoration retention18,19,20. The accumulated stresses of the compression-expansion cycle can cause cracking or spreading of existing cracks and gaps in the interior of the cement layer or along the surface between the cement and tooth21. This study aim is to evaluate the effect of hyperbaric pressure on fracture resistance and fracture patterns in different post systems.

Material and Methods

In this in vitro study, 40 extracted, single-rooted lower premolars, with straight root canals were selected. The inclusion criteria were : straight roots, absence decay, defects, cracks, and/or previous endodontic treatment. The selected teeth were cleaned of both calculus deposits and soft tissue using ultrasonic scaler. Each tooth was placed in 2.5% sodium hipoclorite for 1 hour for surface disinfection than storage in distilled water and prepared within 1 month of extraction. The coronal portion of each tooth was decoronated 2mm above cemento enamel junction using a low speed, water cooled diamond disc (Dentorium International, USA)

All root canals were prepared by one trained operator and the root canal of each tooth was explored using a size #10K-File (Denstply Maillefer, Ballaiques, Switzerland). Endodontic treatment was carried out following a standard crown-down technique using AF Rotary file (Fanta, China) and the E-connect Pro endomotor (Micromega, China). The apical foramen was prepared to size 30 and 0.04 taper. The root canal was irrigated between instruments with 5 ml of 2,5% sodium hipoclorite, distilled water, and 2 ml of 17% EDTA. The final irrigation was carried out with 2ml of 2% Clorhexidin for 1 minute followed by 5ml distilled water. The root canals were dried with absorbent paper points (DiaDent) and filled with bioceramic sealer (One Fill, Korea) and #30/.04 gutta percha points using single cone technique. Extra coronal excess of gutta-percha was removed heated gutta cutter. The canal access was sealed with a temporary restorative material (Caviton, GC).

After storage at 100% humidity for 1 week at 37oC, the coronal seal was abraded by carbide bur (Dentsply, Switzerland) under water cooling and the gutta percha was removed with PeesoReamer using dental loupe (4our eyes, magnification 3,5x), leaving 5mm of apical seal. The post space was then prepared with post drill #2 (Rely X 3M ESPE, USA)to a fixed depth of 10mm from cement enamel junction. The post space was irrigated with distilled water and dried with paper points. All samples was embedded into a wax box to facilitate the post insertion and restoration. Samples were randomly divided in two groups of 20 sample each, depending on post system used. Single Prefabricated Fiber Post for group A and anatomical fiber post for group B.

For Group Single Prefabricated Fiber Post, the post space was etch with 37% phosphoric acid for 30 s and rinse with distilled water, then dried with paper point. The bonding agent was applied to post space and light cure for 10s. The dual cure cement was applied to post space and covered the post and than post was inserted into post space than the cement was cured with light cure for 40s. Then the core and crown were made clinically with direct composite resin bulkfill using a mould.

For Group Anatomical Fiber Post, the glycerine was apllied to post space as separator. The silane was aplliedto prefabricated fiber post's surface and let it dried for 60sthan bonding was apllied to fiber post surface and light cure for 10s. The fiber post than relined with composite resin and inserted to post space and light cure for 10s, the post was taken out and light cure for 40s. the post space was rinse with distilled water and than etch with 37% phosphoric acid for 30 s and rinse again with distilled water, then dried with paper point. The bonding agent was applied to post space and light cure for 10s. The surface treatment applied for fiber post using hyaluronic acid 35% and silane followed by apllied the bonding agent and light cure for 10 s. The dual cure cement was applied to post space and covered the anatomical postand than the anatomical post was inserted into post space than light cure for 40s. the core and crown were made clinically with direct composite resin bulkfill using a mould.

After storage 24 hours in humidity, all sample carried out for a thermoycling process for 200 cycles from 5oC to 55oC. The sample then divided into subgroups of 10 samples. Group SFP1 (Single Prefabricated Fiber Post with 1 ATA air pressure), SFP4 (Single Prefabricated Fiber Post with 4 ATA air pressure), AFP1 (Anatomical fiber post with 1 ATA air pressure), AFP4 (Anatomical fiber post with 4 ATA air pressure). Group SFP1 and AFP1 was kept on the storage with the atmosphere air pressure. Group SFP4 and AFP4 was put into the hyperbaric chamber then subjected to 4 ATA pressure for 25 minutes and decompressed over a 25 minutes period. The 24 cycles were repeated one after the other. After the cycles of hyperbaric, the samples wasembeded into chemically cured resin acrylic 2mm under cemento enamel junction 90o to the X axis.

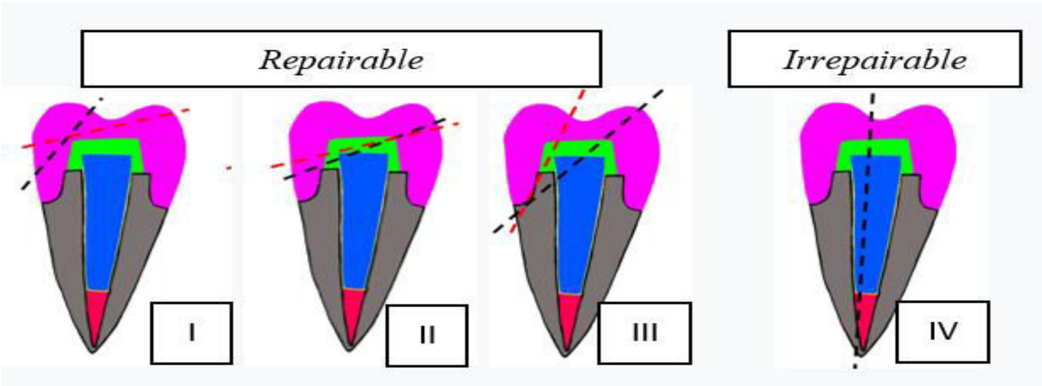
The fracture test was performed using a Universal Testing Machine (UTM) with static load which was applied to the axial tooth at a speed of 0.5 mm/min until fracture occurred and the fracture pattern was observed with dental loupe with 3,5x magnification. The maximum forced was recorded in Newton (N). The type of fracture was classified into four categorial22

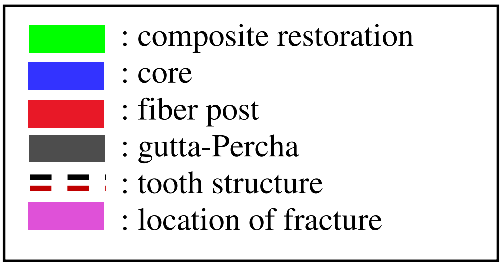
Type I:Fracture only on the direct composite restoration

Type II:Fracture on the direct composite restoration, post and core

Type III:Fracture on the direct composite restoration, post and core, involved the tooth stucture

Type IV : vertical root fracture.





The statistical analysis was performed using the statistical analysis software SPSS 20.0 Descriptive statistics that included mean and standard deviation were calculated. Data were subsequently analyzed using the ANOVA variance to determine wheter significant different exist among tested group then followed by LSD test to determine wheter the different mean in group with hyperbaric pressure and with no hyperbaric pressure were significant or not. While for fracture patterns with categorical data were tested using Kruskal Wallis Test.

RESULT

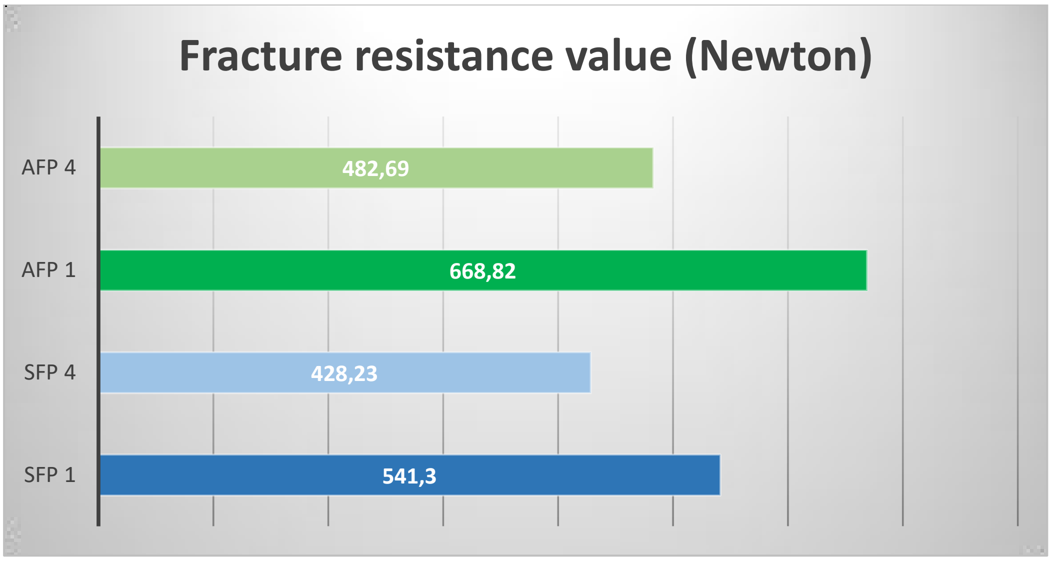
FRACTURE RESISTANCE

The mean values of fracture resistance was541,3 N±79,5 for group SFP1, 428,23 N±68,34 for group SFP4, 668,82 N±90,84 for group AFP1 and 482,69 N±81,57for group AFP4. The mean values of each group wasdignificantly different (p = 0.000)

Tabel 1. Descriptive mean value and standard deviation in each groups

Group	Fracture resistance value (mean ± SD)	
	n	X ± SD
Single fiber Prefabricated 1 ATA	10	541.30 ± 79.50
Single fiber prefabricated 4 ATA	10	428.23 ± 68.34
Anatomic fiber post 1 ATA	10	668.82 ± 90.84
Anatomic fiber post 4 ATA	10	482.69 ± 81.57

*statistically significant p<0.05



According to the LSD test, there was a significantly different mean values of group SFP1 (Single Prefabricated Fiber Post with 1 ATA air pressure) compared to SFP4 (Single Prefabricated Fiber Post with 4 ATA air pressure) p=0.003; AFP1 (Anatomical fiber post with 1 ATA air pressure) compared to AFP4 (Anatomical fiber post with 4 ATA air pressure) p=0.000 and A1 (Single Prefabricated Fiber Post with 1 ATA air pressure) compared to B1 (Anatomical fiber post with 1 ATA air pressure) p=0.000

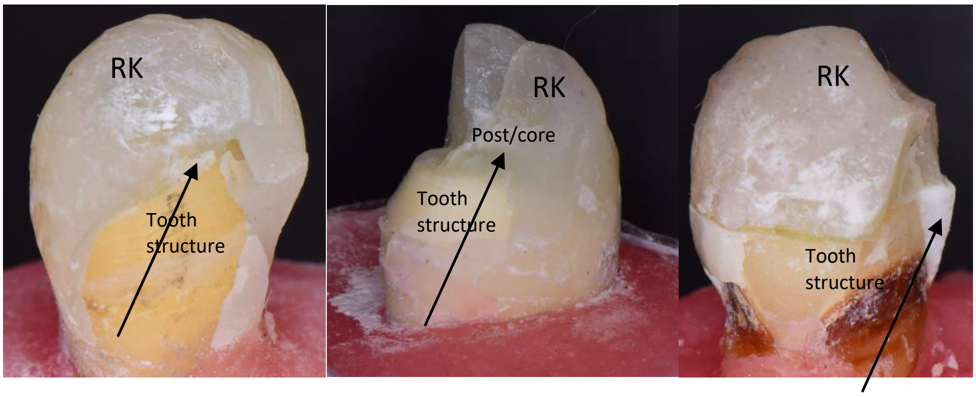
FRACTURE PATTERN

Table 3. Descriptive precentage of Fracture in each groups (%)

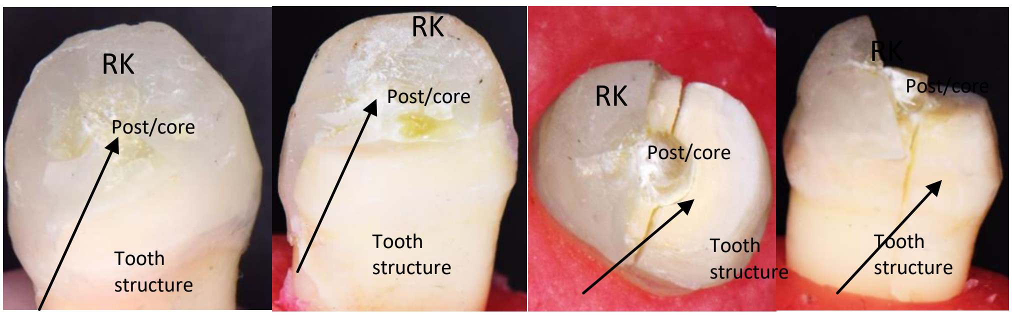
Kelompok	n	Repairable (%)				Irrepairable(%)	
		(Tipe I)Fracture only	(Tipe II) Fracture on	(Tipe III) Fracture	Total	(Tipe IV) Vertical	Total

		on the direct composite restoration	composite restoration -post-core	on restoration -post-core involved the tooth structure		root fracture	
SFP 1	10	30	60	10	100	-	-
SFP 4	10	30	60	-	90	10	10
AFP 1	10	50	30	10	90	10	10
AFP 4	10	30	60	10	100	-	-

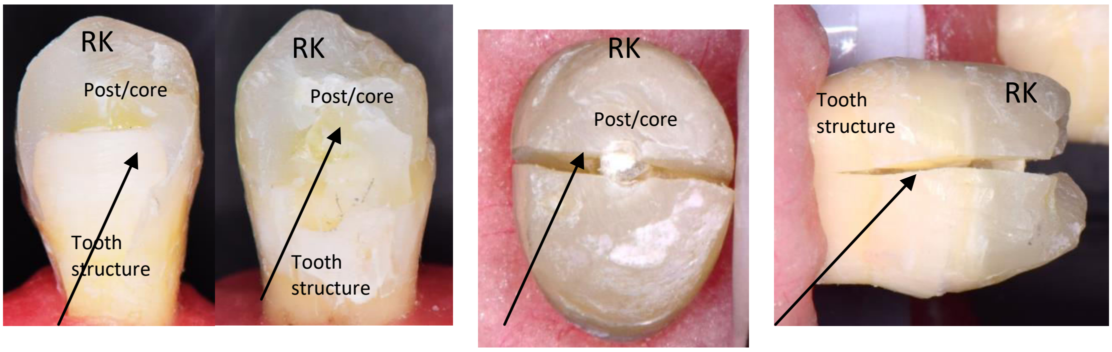
Moreover on the observation of the failure mode, there was no statistically significant difference beetwen each groupsp = 0,958 (p > 0,05). SFP1: 100% fracture repairable (30 % fracture on Composite restoration, 60% fracture on composite restoration-post-core, 10% fracture on restoration-post-core involved the tooth structure); Group SFP4: 90% Fracture Repairable (30 % fracture on Composite restoration, 60% fracture on composite restoration-post-core), 10% fracture irrepairable (vertical root fracture); Group AFP1: 90% fracture repairable (50 % fracture on Composite restoration, 30% fracture on composite restoration-post-core, 10% fracture on restoration-post-core involved the tooth structure) and 10% fracture irrapairable (vertical root fracture); Group AFP4: 100% fracture repairable (30 % fracture on Composite restoration, 60% fracture on composite restoration-post-core, 10% fracture on restoration-post-core involved the tooth structure).



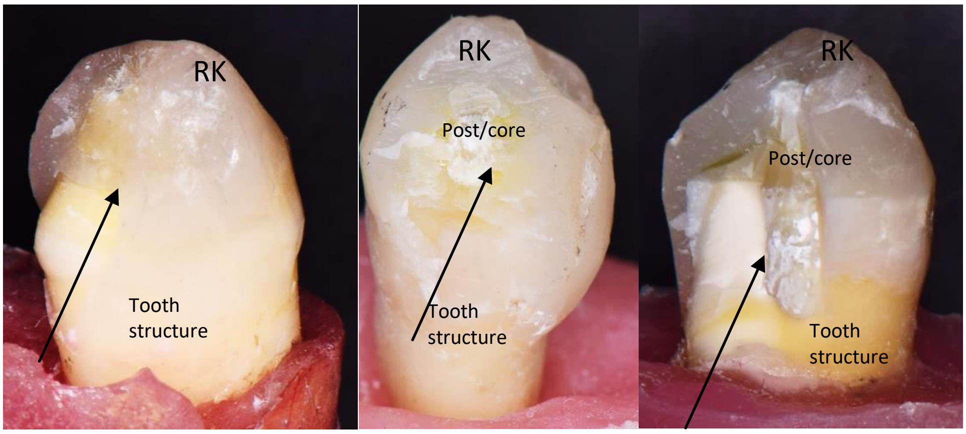
Fracture Pattern in Group SFP1



Fracture pattern in group SFP4



Fracture pattern in group AFP1



Fracture pattern in group AFP4

DISCUSSION

Table 1 shows that the highest fracture resistance value is in the anatomic fiber post group with 1 ATA air pressure. This indicates that the increased adaptation of the post to the root canal will increase the fracture resistance. The results of this study are in line with the study by Silva et al. (2011) and Farahany and Trimurni A (2018)12,14

Root canals have a variety of shapes. Prefabricated fiber posts do not adapt perfectly to the various shape and diameter of the root canal. Poor adaptation will cause the formation of a thick layer of cement which will result in high polymerization shrinkage on the root canal wall. This is a predisposing factor for restoration failure. Shrinkage stress is influenced by the cavity configuration (C-factor) where the C-factor is greatly increased when the fiber post is inserted into the root canal. The C-factor value in endodontic posts cemented into the root canal can reach 200, whereas in intracoronal restorations it only ranges from 1-5.23,24Anatomical fiber post will mimic the root canal shape so it will increase the frictional contact between the post and the root canal wall. The closer the adaptation of the contact between the resin cement, the post and the dentin of the root canal wall, the retention of the fiber post will increase. The anatomic fiber post will enter the root canal firmly, so that the cement pressure against the root canal wall will increase the cement bond contact and the root canal wall, prevent water absorption and reduce porosity in the bond between the post-cement-root canal wall.11,25

Grandini et al. (2005) stated that if the post does not fit properly in the root canal, especially in the coronal 1/3, will produce a thick cement layer and are prone to air bubbles and voids which will increase the risk of failure and shifting of the post.26 Therefore, anatomic fiber posts with good adaptation to the post space have higher retention than single prefabricated fiber posts24 Alkhudairy et al. (2018) and Shafiei et al. (2018) found that the highest push-out bond strength value was found in the use of EDTA as a post space irrigation material. This is due to the efficacy of EDTA in dissolving the smear layer and opening the dentinal tubules so the adhesive material penetrate to the dentinal tubules. In this study, irrigation of the post space was carried out using aquadest, where the aquadest did not dissolve the smear layer and did not open the dentinal tubules.27,28

Resin cement and adhesive system is one of the important factors for the retention of fiber post to the root canal wall. Study by Amaral et al. in 2009 found that fiber posts cemented with resin cement with an etch and rinse adhesive system showed a better value of push out bond strength than cementation with resin cement using a self adhesive system.29This is related to the bonding mechanism using micromechanical retention and chemical bonds with hydroxyapatite. The etch and rinse adhesive system eliminates the thin smear layer on the dentin by etching phosphoric acid and provides good micromechanical retention.28,29

In this study, it was seen that the sample group that received 4 ATA hyperbaric pressure had a significantly lower fracture resistance value than the sample that did not experience hyperbaric pressure. This shows the hypothesis is accepted, that there is an effect of hyperbaric pressure on different post endodontic post systems on fracture resistance.

Shrinkage that occurs during the polymerization of resin cement is one of the causes of gaps that can cause trapped air bubbles. The gap formed between the post and the root canal wall can reduce retention and even cause debonding of the post.30,31 During the dive simulation, when in hyperbaric conditions the air trapped will compressed and it will allowtheanother bubblesenty into the interfacial gap and when the diver return to the 1 ATA air pressure, the air bubbles will expand and press against the entire surface of the root canal wall. The accumulated stresses of the compression-expansion cycle can cause cracks within the cement layer and along the interfacial between cement and the root canal wall.21

In this study, there were no significant differences in fracture patterns between single prefabricated fiber post systems and anatomic fiber posts without hyperbaric pressure or with hyperbaric pressure. In this case the hypothesis is rejected, which means that hyperbaric pressure does not affect the fracture pattern on fiber post restorations. Fractures in this study 90%-100% were repairable fractures. Study by Farahanny W and Trimurni A (2018) showed that almost all samples had repairable fractures (in the single glass fiber group it was 80% repairable and in the anatomical post group it was 100% repairable)14. Frater et al. (2016) found that endodontically treated teeththat were restored using glass fiber using both single post and multi-post techniques did not have a different fracture pattern, where 70% of each sample group had irrepairable fractures.32Torabi and Fatahhi (2009) also found that endodontically treated teeththat were restored using 70% glass fiber posts had repairable fractures.33

In this study, the fracture pattern was almost the same in each sample, the fracture pattern was above the CEJ and almost all of them were in the composite resin material and the core post. This illustrates that the stress concentration occurs in the coronal 1/3 of the tooth, the composite resin restoration material. When a vertical load is applied, the stress concentration is in the composite resin restoration and is transmitted to the fiber post, the fiber post has a shock absorber effect so the stress concentration on the roots is lower. This is in accordance with the results of research conducted with FEA by Maceri et al. (2007) and Pinto et al. (2018), namely in post-endodontic teeth that were restored using maximum stress fiber posts, there was a loading contact point that was seen in the core-dentin interfacial area. The use of fiber posts that have a similar modulus of elasticity with dentin will protect the dentin and provide a lower stress concentration on the dentin.34,35

LIMITATION

The limitation of this study is that it has not replicated the clinical condition of the teeth in the alveolar bone. The fracture test was carried out using a static load where the direction of the applied load was parallel to the axial tooth. This conditiononly describes centric occlusion in the oral cavity. Observation of fracture pattern was also carried out using a dental loupe with 3.5x magnification.

CONCLUSION

In this study, it was seen that there was an effect of hyperbaric pressure on fracture resistance in different post endodontic post systems. This can be influenced by the adaptation of the fiber post to the root canal as well as the retention and resistance of the post in the root canal. The use of irrigation materials, the presence of a smear layer, the use of adhesive and resin cement systems as well as the air pressure conditions in the dive simulation affect the retention of the fiber post which will affect the resilience of the post restoration when under pressure when functioning in the oral cavity.

In the pattern of fractures that occur, there is no significant difference, where almost all samples have repairable fractures so that the restoration can be repaired. This is because the modulus of elasticity of the fiber post resembles that of dentin and the monoblock system of the post, resin cement, dentin and composite resin restorations results in an even distribution of the teeth under load.

REFERENCES

1. Mortazavi V et al. 2012. Fracture Resistance Of Structurally Compromised And Normal Endodontically Treated Teeth Restored With Different Post Systems : An In Vitro Study. Dent Res J (Isfahan); 9 (2) : 185-91

2. Schwartz RS, Robbins JW. 2004. Post Placement And Restoration Of Endodontikally Treated Teeth : A Literature Review. Journal Of Endodontiks; 30(5): 289-301.

3. Mclaren JD et al. 2009. The Effect Of Post Type And Length On The Fracture Resistance Of Endodontically Treated Teeth. The Journal Of ProstethicDentistry:101:174-82.

4. Zhou L, Wang Q. 2013. Comparison Of Fracture Resistance Between Cast Post And Fiber Posts: A Meta Analysis Of Literature. Journal Of Endodontics;39:11-5.

5. Parcina I, Baraba A. 2016. Esthetic Intracanal Posts. Acta Stomatol Croat; 50(1): 143-50.

6. Tay F R, Pashley D H. 2007. Monoblocks In Root Canals: A Hypothetical Or A Tangible Goal. J Endod ;33:391–8.

7. Al-Aajam W, Al-Moaleem M, Shareef M. 2013. Restoration Of Endodontikally Treated Teeth: Materials Review. Cairo Dental Journal. 8: 1-17.

8. Abduljabbar T, et al. 2011. Fracture Resistance Of Three Post And Core Sistems In Endodontikally Treated Teeth Restored With All-Ceramic Crowns. King Saud University Journal Of Dental Sciences ; 3 : 33-8.

9. Evren OK, Dilber E, Altunsoy M, Kalkan A, Demir N. 2014. Comparison Of The Effect Of Three Different Post Systems On Root Fracture. J Rest Dent; 2: 125-9.

10. Panitiwat P, Salimee P. 2017. Effect Of Different Composite Core Materials On Fracture Resistance Of Endodontikally Treated Teeth Restored With FIBER Posts. J Appl Oral Sci; 25(2): 203-10.

11. Rocha A T, Goncalves L M, et al. 2017. Effect Of Anatomikal Customization Of Fiber Post On The Bond Strength Of A Self-Adhesive Resin Cement. International Journal Of Dentistry : 1-7.

12. Faria ACL, et al. 2011. Endodontikally Treated Teeth: Characteristics And Considerations To Restore Them. Journal Of Prosthodontic Research; 55 : 69–74.

13. Faria-E-Silva AL, Perosa-Filho CF, Menezez MS, Silveira DM, Martins LRM. 2009. Effect Of Reline On Fiber Post Retention To Root Canal. J Appl Oral Sci:17(6):600-4.

14. Farahanny W dan Trimurni A. 2018. PengaruhSistemPasakFiber Yang Berbeda Pada SaluranAkar Yang Lebar SetelahPerawatanEndodontiTerhadapKetahanan Fraktur Dan Pola Fraktur. Tesis. Indonesia : Universitas Sumatera Utara.

15. Kraft S H. 2016. U S Navy Manual Diving, Revision 7. Direction Of Commander Naval Sea Sistems Commands; 9-63.

16. Calder And Ramsey. 1983. Ondontecrexis-The Effects Of Rapid Decompression On Restored Teeth. Journal Of Dentistry; 119 (4) : 318-23.

17. Musajo F, Passi P, Girardelo G B, Rusca F.1992. The Influence Of Environmental Pressure On Retentiveness Of Prosthetic Crowns, On Experimental Study. Quintessence Int;23:367-9.

18. Zadik Y, et al. 2006. Dental Fractures On Acute Exposure To High Altitude. Aviation, Space, And Environmental Medicine; 77(6): 654-7.

19. Zadik Y. 2009. Dental Barotrauma. Int J Prosthodont; 22: 354–7.

20. Rajpal PS, et al. 2014. Dental Barotrauma AndBarodontalgia. Journal Of Medical Science And Clinical Research; 2(12): 3477-83.

21. Lyons K M, Roda J C, Hood J. 1999. The Effect Of Environmental Pressure Changes During Diving On The Retentive Strength Of Different Luting Agents For Full Cast Crowns. J ProstethicsDent;78:522-7.

22. Maria D G , Farmakis E.T , Eliades G.C. 2018. Effect Of Load Cycling On The Fracture Strength/Mode Of Teeth Restored With FRC Posts Or A FRC Liner And A Resin Composite. Biomed Research International; 2018 : 1-10.

23. Aksornmuang J, Nakajima M, Senawongse P, Tagami J. 2011. Effects Of C-Factor And Resin Volume On The Bonding To Root Canal With And Without Fibre Post Insertion. Journal Of Dentistry; 39: 422-9.

24. Helen-Cot Marcos RM Et Al. 2016. Infulence Of The Resin Cement Thickness On The Push-Out Bond Strength Of Glass Fiber Posts. Brazilian Dental Journal; 27 (5): 592-8.

25. Andrioli ARV, Coutinho M, Vasconcellos AA, Miranda ME. 2016. Relining Effects On The Push-Out Bond Strength Of Glass Fiber Posts. Rev OdontolUNESP : 45(4): 227-33.

26. Grandini S, Goracci C, Monticelli F, Borracchini A, Ferrari M. 2005. SEM Evaluation Of The Cement Layer Thickness After Luting Two Different Posts. J AdhesDent;7:235-240.

27. Alkhudairy FI, et al..2018. The Effects Of Different Irrigation Solutions On The Bond Strength Of Cemented Fiber Posts. Clinical, Cosmetic And Investigational Dentistry: 10: 221-30.

28. Shafiei F, Mohammadparast P, Jowkar Z. 2018. Adhesion Performance Of A Universal Adhesive In The Root Canal: Effect Of Etch-And-Rinse Vc Self-Etch Mode. Plos ONE: 13(4) : 1-14.

29. Amaral FR, et al. 2015. Direct Anatomikal Posts For Weakened Roots: The State Of Knowledge. Scientific Journal Of Dentistry; 2 : 13-20.

30. Geramipanah F, Sadighpour L, Assadollahi R. 2016. The Effect Of Environmental Pressure And Resin Cements On The Push-Out Bond Strength Of A Quartz Fiber Post To Teeth Root Canals.UHM ; 43 (2): 143-50.

31. Gulve MN Dan Gulve ND. 2013. The Effect Of Pressure Changes During Simulated Diving On The Pull Out Strength Of Glass Fiber Post. Dent Res J (Isfahan); 10 (6): 737-43.

32. Frater M et al. 2016. In Vitro Fracture Resistance Of Premolar Teeth Restored With Fiber Reinforced Composite Posts Using A Single Or Multi Posts Technique. Aust Endod J: 1-7.

33. TorabiAndFattahi. 2009. Fracture Resistance Of Endodontically Treated Teeth Restored By Different FRC Posts : An In Vitro Study. Indian J Dent Res: 20(3): 282-7.

34. Maceri F, Martignoni M, Vairo G. 2007. Mechanical Behaviour of endodontic restorations with multiple prefabricated posts: A finite-element approach. Journal of Biomechanics;40(11):2386-98.

35. Pinto CL, et al. 2017. The Influence Of Post Sistem Design And Material On The Biomechanical Behavior Of Teeth With Little Remaining Coronal Structure. Journal Of Prosthodontics : 1-7.