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IN VITRO EVALUATION OF FLEXIBILITY OF NEWER SPLINTS

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ABSTRACT

Aim: The aim of the study was to compare the flexibility of three different splints and to determine their peak load failure in fracture pattern.

Material and Methods: Three different splints (wire-composite, single layer fibre glass and fibre reinforced Everstick splint) were adapted to the extracted Human incisors, placed in a non-rigid fashion on the experimental dental models designed for the study. Stress analysis was conducted on the test specimens by applying both static axial and 45° oblique force with linear increasing intensity ranging from 0-50N and 0-30N respectively both with and without splints using universal testing machine. For each loading direction, the energy required to modify the position of the teeth at increasing applied forces was recorded for specimens with and without splints and the difference between two values (ΔE) was determined, which corresponds to the rigidity of the materials.

Results: For both axial and oblique tests, fibre reinforced splint had shown least ΔE values (0.02±0.08 in axial, 0.01±4.05 in oblique) while wire-composite had shown highest ΔE values (0.67±2.56 in axial, 1.42±5.16 in oblique).

Conclusions: Fibre reinforced splint could be an ideal alternative for splinting traumatized teeth, as it exhibits a lower energy variation needed for deformation and conducive to optimal periodontal healing during immobilization.

KEYWORDS: splints, flexibility, load failure, fracture pattern

INTRODUCTION

Traumatic dental injuries(TDI) occur with great frequency in children and young adults, comprising 5% of all injuries.[1] The external impact in traumatic situations causes neurovascular bundle displacement and periodontal ligament damage, which effects the posttraumatic healing in pulp revascularization and periodontal fibre reorganization.[2] They present a continuing clinical and dental public health problem and consequently, proper diagnosis, treatment planning and follow-up are important to assure a favourable outcome.[3]

Splinting or stabilization of affected teeth was known to be one of the critical phases of treatment of traumatized teeth[4] that are displaced, subluxated, luxated, avulsed, or root fractured.[5,6]

Dental splinting facilitates repositioning of displaced teeth to their original location and ensures adequate fixation with reduced pain and improved

comfort along with protection against traumatic forces during healing period.[7]

Traditionally, rigid splinting has been the treatment of choice,[8] but over the last few decades, the knowledge on repair and healing of traumatically dislocated teeth has grown and treatment principles have changed.[9]The longer periods and rigid splints that increase risk of healing complications[10] are being replaced with shorter period and flexible splints[9], where mechanical stimulus exerted by light movement of teeth favours revascularization process and is capable of preventing tooth ankylosis and maintaining the vitality of Hertwig's epithelial root sheath.[11]

For a long time, wire composite splints had been used, but because of the common failure of these splints at the resin-tooth interface due to less bond strength,[12] recently fibre glass splints[13] had been developed. However, as the advocated splints were difficult to fabricate and remove, contributing to the injury of soft and hard supporting tissues, the development of newer materials had been encouraged.[14] Everstick PERIO, the new generation fibre reinforced splint is comprised of silanated E- glass fibre and was claimed to be suitable splinting material.

The aim of this study was (1) to evaluate and compare the flexibility of fibre reinforced splints (Everstick PERIO) with that of wire-composite and single layer fibre glass splints, and (2) to determine the peak failure load in fracture pattern of the three splints.

MATERIAL AND METHODS

Figure 1 illustrates the armamentarium used for the study. The study design was approved by the Ethical Committee, GITAM dental College and Hospital, Visahkapatnam, India.

EXPERIMENTAL MODEL

Acrylic resin experimental models(2 x 5 cm) were fabricated and the substrate for testing are the Human central and lateral incisors (12,11,21) extracted for periodontal reasons. The

right central incisor(11) served as the traumatized tooth with increased mobility, while the right lateral and left central incisors(12,21) served as adjacent uninjured teeth with normal mobility as described in detail in Cengiz et al.[15] (2006). The PDL simulation around the tooth was provided with hydrophilic addition silicone impression material (Gingifast elastic, Zhermack, Italy). Initially, the entire root surface of the extracted tooth was coated with modelling wax (No.2, HDP, India) using dip-wax technique and the thickness of the wax coating was reduced carefully using a spatula to 0.3mm around teeth with an additional apical 3mm thickness to allow small vertical movement to injured tooth 11. Secondly, an irreversible hydrocolloid (Algitex, DPI, India) impression of the testing jig was made to create a mold and acrylic resin block was prepared by sprinkle on method in the created mold space. During the dough stage of polymerization, previously wax coated teeth were inserted and the position of the three teeth was adjusted according to the arch form in the centre of the acrylic blocks with digital caliper. After polymerization, teeth were removed and wax was carefully removed with spatula and slight flow of hot water. The root surface was then covered with a mix of hydrophilic silicone impression material and was inserted into the created sockets in the acrylic resin block. Upon polymerization, coating was removed from the root and the thickness of the coating was measured with digital caliper and was adjusted to the desired levels. Thus, experimental acrylic resin blocks with three sockets for one traumatized and two supporting teeth were fabricated for testing the splint materials. After coating the root surfaces of the teeth with a mix of silicone impression material, they were stabilized

in the created sockets and were randomly divided into three groups for testing.

SPLINT MATERIALS

Three different splints used for testing were wire-composite, single layer fibre glass and Everstick PERIO and divided into three groups where, group 1 constitutes wire-composite (Konark, India), group 2 constitutes single layer fibre glass (Instafibre, RRP, India) and group 3 constitutes Everstick PERIO (Everstick PERIO,GC, India). The acid-etched bonded procedure for the stabilization of the splints in all the three groups was done in a similar way.Each of the groups were divided into four subgroups with five samples each based on the direction of the load and presence or absence of the splint.

GROUP 1: WIRE- COMPOSITE SPLINT (Figure 2)

The labial surfaces of the teeth are etched for 30sec using 37% ortho-phosphoric acid gel (Dental Etch, D-Tech, India) and rinsed off with air-water spray and air dried. A layer of bonding agent (Tetric N bond universal, Ivoclar Vivadent, India)was applied with a microbrush (Safe Plus, NHC, India) over etched surface and cured for 20sec.0.03' stainless steel round orthodontic wire (Konark, India)cut to desired length was adjusted and secured against the teeth surface with light cure resin composite (3M ESPE Filtek™ Z350 XT) and polymerized for 40sec.

GROUP 2: SINGLE LAYER FIBRE GLASS SPLINT (Figure 2)

Single layer fibreglass (Instafibre, RRP, India) was measured, cut and carefully handled until wetted with bonding resin, followed by adaptation with thin layer of flowable composite (Restofill N Flo, Anabond,

India) on the teeth surface, polymerized and finally secured with composite resin and cured for 40sec.

Figure 1. Armamentarium used for the study.

Figure 2. Wire-composite splint, Single layer fibre glass splint and Everstick PERIO slint.

GROUP 3: EVERSTICK SPLINT (Figure 2)

The fibre reinforced Everstick (Everstick PERIO, GC, India) splint was cut to size, removed from white protective paper with tweezers and was placed on the cured bonding agent with 0.5mm layer flowable composite as per manufacturer instructions. The positioning of the splint was done as incisally as possible to minimize the forces and in such a way that the fibre is precuredin place, one tooth at time, for about 5 sec and then pressed into approximal spaces to allow interproximal flexibility and finally the entire splint was coverd with resin composite and cured for 40sec.

TESTING THE SAMPLES:

Stress and movement analysis was performed to evaluate rigidity of the samples by assessing the strain energy using universal testing machine (INSTRON 8801) (Figure 3). The samples were subjected to a static axial and 45° oblique force of linear increasing intensity ranging from 0-50 Newtons(N) and 0-30N respectively. The load was applied at the incisal margin of injured central incisor tooth 11 both without and with splints for five times, accounting a total of 20 experiments for each splint. The extent of shift of the tooth without splint was carried out each time to evaluate the flexibility of the different splinting methods taking into account

the inevitable small differences in thickness in the supporting material from one test to another.

Figure 3. Testing of samples axially.

The linear increasing forces of 0-50N are chosen in the axial direction as they fall into the physiologic range of masticatory forces[16] and the maximum applied force in oblique direction was 0-30N to compensate for the broader movements caused by oblique force. The unsplinted samples acts as controls and reference parameters for splinted samples and by elaborating the force-movement graphic of the machine, movement of the tooth at maximum applied forces was recorded. The catastrophic failure of splints was observed in both directions and the peak load of fracture for each sample was also tabulated by applying forces at the rate of 1mm/min until the splint was dislodged.

RESULTS

After all the samples were tested, the movements of teeth at the maximum applied forces both without and with splint in axial direction at 50N and oblique direction at 30N were tabulated and the mean movements are calculated (Table 1). The mean movement in axial direction for unsplinted and splinted samples of group 1,2 and 3 were 0.60±0.10, 0.56±0.17, 0.64±0.15 and 0.43±0.08, 0.54±0.14, 0.65±0.14 respectively and that of the observed mean movement in oblique direction were 0.43±0.12, 0.60±0.19, 0.50±0.16 and 0.22±0.04, 0.50±0.22, 0.41±0.21 for unsplinted and splinted samples of wire-composite, single layer fibre and Everstick groups respectively.

To assess the rigidity of the samples for linear increasing applied forces over time, the strain(deformation) energy was calculated and was given by simplified formula: $E = 1/2\ F_{max}S_{max}$, where E= strain/deformation energy(mJ) and represents work done to move the teeth (F_{max}= maximum load applied(N). S_{max}= allowed tooth movement(mm) before irreversible deformation of the splint occurs

With the applied formula, deformation energy was calculated for both axial (E_A) and oblique (E_O) directions without (E_{A1}), (E_{O3}) and with (E_{A2}), (E_{O4}) splints and mean was tabulated. The mean axial deformation energy for samples without splints (E_{A1}) for groups 1,2 and 3 were 1.51, 2.61 and 1.61 while for splinted samples (E_{A2}) was observed to be 2.18,2.80 and 1.63 respectively. The mean deformation energy in oblique direction of groups 1,2 and 3 were 4.18,3.27 , 4.43 for unsplinted samples (E_{O3}) and 5.60, 3.99, 4.44 for samples with splints (E_{O4}) respectively.

The difference between the mean deformation energy (ΔE) corresponds to the rigidity of the samples; higher the ΔE , more rigid is the material. The ΔE obtained from five tests performed without and with splints in axial (ΔE$_A$) and oblique (ΔE$_O$) is calculated. To compare the mean values of deformation energy, descriptive statistics of observed values were taken and a series of student's t-test for independent variables were performed (Table 2) and the mean difference of deformation energy in axial (ΔE$_A$) and oblique(ΔE$_O$) direction were 0.67±2.36, 0.19±0.60, 0.02±0.08 and 1.42±5.16, 0.73±4.26, 0.01±4.05 respectively for groups 1,2 and 3. The mean values of the peak load failure are also tabulated (Table 3).

In the study, group 3 showed highest flexibility in both directions and the high elasticity was demonstrated by low deformation energy (ΔE$_A$=0.02±0.08, ΔE$_O$=0.01±4.05) and group 3 has exhibited failure at very high loads corresponding to the higher strength of the material compared to the other two groups. But independently from each loading direction, the deformation energy recorded with and without splint was not significant(p>0.05).

DISCUSSION

Splinting of teeth after trauma was known to be a common procedure.[17] Many splinting techniques and materials have been used and in this context, there are two biomechanical factors that appear as prerequisites to optimize healing [1 a healing tooth-periodontal ligament interface to experience strains within physiological limits of 50- 1500μ[18] and 2] promotion of healing interface by micromovement of tooth in traumatized socket.[19]

Microtension across healing wound promotes the production[20]and maturation[21] of collagen and maintains sufficient blood circulation and venous return in healing ligament,[22]thus encouraging revascularization by accelerating the rate of periodontal reorganization and reattachment.[15]

Complete immobilization prevents healing due to stress deprivation which changes fibroblasts

from anabolic to catabolic state, reducing collagen mass.[23]

The study conducted by Berthold et al.[24] (2011)found that the wire length influences rigidity and recommended splinting only one uninjured tooth bilaterally. Ebeleseder et al.[25] (1995) in a study of 103 post-traumatic splints made of composite resin and 0.017x0.025" orthodontic steel wire found that there was no benefit from extending the splint to more than one adjacent firm tooth. Hence, in the present study the two supporting teeth on the either side of the injured tooth were splinted.

Table 1. Movements recorded at 50N and 30N.

Sample	Group 1 wire-composite				Group 2 Single layer fibre glass				Group 3 Everstick PERIO			
	Axial 50N		Oblique 30N		Axial 50N		Oblique 30N		Axial 50N		Oblique 30N	
	Without splint	With splint	Without splint	With splint	Without splint	With splint	Without splint	With splint	Without Splint	With splint	Without splint	With splint
1	0.67	0.42	0.32	0.21	0.55	0.51	0.39	0.24	0.81	0.79	0.45	0.31
2	0.69	0.48	0.47	0.27	0.67	0.62	0.51	0.46	0.73	0.74	0.69	0.66
3	0.54	0.52	0.37	0.15	0.27	0.32	0.91	0.83	0.45	0.47	0.37	0.22
4	0.45	0.24	0.46	0.25	0.61	0.59	0.57	0.37	0.54	0.53	0.34	0.23
5	0.67	0.54	0.53	0.24	0.69	0.67	0.64	0.59	0.69	0.67	0.63	0.61
Mean	0.60	0.43	0.43	0.22	0.56	0.54	0.60	0.50	0.64	0.65	0.50	0.41
SD	0.10	0.08	0.12	0.04	0.17	0.14	0.19	0.22	0.15	0.14	0.16	0.21

Table 2. Mean comparison of EA1, EA2 and ΔE in axial direction and EO3 , EO4 and ΔE in oblique direction for wire composite, single layer fiber &Everstickperio by using t-test.

Group	Mean					Mean				
	E_{A1}	E_{A2}	ΔE_A	SD	P value	E_{O3}	E_{O4}	ΔE_O	SD	P-value
Wire-composite	1.51	2.18	0.67	2.36	0.51	4.18	5.60	1.42	5.16	0.47
Single layer fibre	2.61	2.80	0.19	0.60	0.91	3.27	3.99	0.73	4.26	0.76
Everstick	1.61	1.63	0.02	0.08	0.94	4.43	4.44	0.01	4.05	0.99

EA1 = mean axial deformation of energy without splint

EA2 = mean axial deformation energy with splint

ΔEA = difference between mean deformation energy in axial direction

EO3 = mean deformation energy in oblique direction without splint

EO4 = mean deformation energy in oblique direction with splint

ΔEO = difference between deformation energy in oblique direction

A variety of models can be used to evaluate splint rigidity, each of them having advantages and disadvantages. Oikarinen[26] (1988), Filippi et al.[27] (2002) and Berthold et al.[28] (2011) used commercially available acrylic resin models, where tooth mobility was manipulated by placing silicon rubber pieces between root and alveolar socket, and teeth were fixed with apical screws but unlike with natural enamel, improved adhesion between tooth surface and resin composite is not possible. Oikarenin et al.[5] (1992) tested splint rigidity on dissected sheep mandibles but the potential risk of disease infection made it difficult. Von Arx et al.[29] (2001) performed rigidity testing on Human volunteers but the abscence of traumatically loosened teeth with potential for damage to enamel during

splint removal were major drawbacks. To avoid the above disadvantages, Kwan et al.[4] (2012) used Human cadvaric model to test the splint rigidity but the lack of access to cadavers makes the technique very difficult. Hence, in the present study, acrylic resin models were used for easy handling, low variability and to improve the adhesion by acid etching, natural Human teeth were used.

Table 3. Peak load failure recorded at 50N and 30N.

Sample	Group 1 (wire composite)		Group 2 (single layer fibre glass)		Group 3 (everstick)	
	Axial	Oblique	Axial	Oblique	Axial	Oblique
	50N	30N	50N	30N	50N	30N
1	62	47	82	60	135	104
2	65	43	74	64	127	112
3	59	51	89	59	131	114
4	64	49	77	63	129	107
5	57	46	72	57	125	110
Mean	61	47	79	61	129	109

Resin splints are difficult to clean and leads to gingival irritation,[14] wire-composite splints commonly fail at the resin-tooth interface due to less bond strength[12] and recently developed fibre glass splints were difficult to cut.[13] Therefore, in this study, a recently introduced flexible material Everstick Perio was also included.

Everstick®PERIO, a new biocompatible, esthetic material made from silanated E glass fibres was comprised of polymer/resin gel matrix for reinforcing dental composite. These unidirectional fibre reinforced splints, cured directly on teeth, offer strong yet elastic splint and various advantages such as ease of adaptation to dental contours, less time consumption, reliable bonding with interproximal flexibility, superior durability, and elastic modulus close to dentine. The geometry of tight fibre matrix leads to good integration of fibres with composite and thus have good clinical longevity.

The best semi-physiological mobility can be obtained by flexible splints. In this study, the Everstick group showed highest flexibility followed by single layer fibre glass group, with significant difference between the mean values of the deformation energy with and without splinting(p>0.05), and ΔE_A showed significantly lower values compared to other samples. The higher flexibility of the Everstick group was also confirmed by results of analysis performed in oblique direction. The results suggest that although wire-composite splints showed flexibility, they may not give the traumatized tooth the mobility, it needs for optimal healing. Infact, independently from the loading direction, the recorded deformation energy was not significant. However, the observed highest flexibility of Everstick group compared to other groups can be ascribable by their low deformation energy. The same group exhibited highest strength by exhibiting splint failure at very high loads.

Oikerinen et al.[5] (1992) proved that luxated teeth splinted for longer periods should be fixed by vertically flexible splints to promote healing. Berthold et al.[9] (2009) reported in an in vitro study that wire composite splint of 0.8mmx18mm was found to be rigid while 0.41 rectangular orthodontic wire was flexible. The results of study by Kwan et al.[4] (2012) found composite splints and composite and wire splints where the wire diameter was greater than 0.4mm were deemed to be rigid splints. Similar findings were noted in the present study with more pronounced reduction of tooth mobility following wire- composite splint application.

Common failure of thin wire-composite splints occurs at wire- resin interface and hence while using composite material for wire-composite splints, some surface treatment of wire is essential, which is time-consuming and difficult to remove.[12] The stiffness of different splints was evaluated and it was observed that flexibility of wire-composite splints was much related to wire diameter and that of fibre glass splint was similar to twist flex steel wire. They presented that fibre glass splints were easy to apply but are difficult to cut with fraying of fibres,[13] similar to the observations of present study.

Although all tested materials in the present study fulfill the current requirements of a dental trauma splint, [30] they should be passive, exert no orthodontic forces and should not affect hygiene or interfere with occlusion while maintaining aesthetic demands of the patient. With all these requirements in mind and based on the data obtained

from this study, the newly developed EverstickPerio splint can be suitable for treatment of traumatic lesions involving the supporting tissue of the tooth.

CONCLUSIONS

Within the inherent limitations of the present study with the lack of more complex structure of the biological dental tissues, vital periodontal ligament and the material being slightly expensive, the experimental data provided on the flexibility of different splint systems had shown that the unique combination of esthetics, strength, flexibility and reliable bonding makes the new generation fibre reinforced Everstick splints more conducive to optimal healing. The ease of application and removal of the material may benefit patient and practitioner alike and could be a better and good alternative method for splinting and stabilizing traumatized teeth.

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