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 – 6, Issue – 3, June - 2023, Page No. : 474 – 483

A comparative evaluation of fracture toughness of an auto polymerizing resin v/s light cure resin for use in strip crown in primary anterior teeth : An invitro study

[1]Dr. Menaka S, Postgraduate, A J institute of Dental Sciences, Mangalore, India.

[2]Dr. Pusa Jagdish, Postgraduate, A J institute of Dental Sciences, Mangalore, India

[3]Dr. Priya Shetty, Reader, A J institute of Dental Sciences, Mangalore, India.

[4]Dr. Sowmya B Shetty, HOD, A J institute of Dental Sciences, Mangalore, India.

[5]Dr. Nikita Patil, Postgraduate, A J institute of Dental Sciences, Mangalore, India.

[6]Dr. Samruddhi K Shetty, Postgraduate, A J institute of Dental Sciences, Mangalore, India.

Corresponding Author: Dr. Menaka S, Postgraduate, A J institute of Dental Sciences, Mangalore, India.

Citation of this Article: Dr. Menaka S, Dr. Pusa Jagdish, Dr. Priya Shetty, Dr. Sowmya B Shetty, Dr. Nikita Patil, Dr. Samruddhi K Shetty, "A comparative evaluation of fracture toughness of an auto polymerizing resin v/s light cure resin for use in strip crown in primary anterior teeth." An invitro study", IJDSIR- June - 2023, Volume – 6, Issue - 3, P. No. 474 – 483.

Type of Publication: Original Research Article

Conflicts of Interest: Nil

Abstract

Aim- The aim of the study was to evaluate and compare the fracture toughness of an auto polymerizing resin protemp[tm] 4(3M[TM] ESPE) and light curing nano-composite resin filtek[tm] Z350 XT (3M[TM] ESPE) for restoring primary anterior teeth with strip crown.

Materials and methods: Forty-two exfoliated primary maxillary central incisors were collected and were randomly divided into two groups (21 in each group). Measurements were taken before and after tooth preparation by two examiners. All the teeth were etched, rinsed, and dried following by bonding agent application and then light cured for 30 seconds. In group I, Protemp 4 (3M ESPE, Seefeld, Germany) was filled in strip crown and placed on prepared tooth specimen and left to auto polymerize for 5 minutes. In group II, strip crowns were filled with Filtek Z350 XT (3M ESPE, Seefeld, Germany) and light cured for 30 seconds. The strip crowns were removed, and the teeth were stored in saline for 24 hrs and thermocycling was done using thermocycling processing unit. After 24 hrs fracture toughness was tested using the universal testing machine until fracture. Fracture toughness of the two groups was recorded and analysed statistically using unpaired Student's "t" test.

Results: The mean fracture toughness for protemp[tm] 4 (386.77 N) was higher when compared with filtek[tm] Z350 XT (377.24 N). This difference was not statistically significant with test value of 0.208 and p value>0.05 (i.e . 0.836).

Conclusion: Auto polymerizing resin (protemp^{tm} 4) can be considered as an alternative to light curing composite resin (filtek^{tm} Z350 XT) for restoring primary anterior tooth with strip crown.

Keywords: strip crown; anterior restoration; fracture toughness; esthetic restoration; composite; protemp^{tm} 4; filtek^{tm} Z350 XT; light cure resin; auto polymerizing resin;

Introduction

Oral health has a direct impact on the general health of the child. Early loss of primary teeth may lead to the development of parafunctional habits like tongue thrusting, and the inability to pronounce fricative and sibilant sounds, leading to speech problems, psychologic problems, reduced masticatory efficacy, and loss of vertical dimension of occlusion, thereby affecting the quality of life of the child.

The objectives of restorative therapy include removing cavitation or defects to eliminate areas that are susceptible to caries, stopping the progression of tooth demineralization, restoring the integrity of tooth structure, preventing the spread of infection into the dental pulp, and preventing the migration of teeth due to loss of tooth structure.[1]

To restore carious primary anterior teeth, the American Academy of Pediatric Dentistry (AAPD) has recommended the use of composite strip crowns, open-faced stainless-steel crowns, pre-veneered stainless-steel crowns and zirconia crowns.[2]

Esthetic restoration of primary anterior teeth can be challenging because of the small size of the teeth, the proximity to the pulp (thin enamel), the lack of surface area for bonding, and child's behavior during treatment.[3]

A primary objective of placing a crown is to achieve an esthetic improvement and correction of the texture, shade, and shape of the tooth which restores the physiological and functional form. That helps to the prevention of tooth migration, bone loss, and arch collapse[4]

Strip crown using celluloid crown forms is the most popular method of restoring primary anterior teeth. It was first introduced in 1979 by Webber and colleagues. Strip crowns are available in six sizes (No.1 to 6) (Unitec Strip Crown, 3M ESPE, St Paul). It is the first choice of restoration, mainly because of its superior aesthetics and ease of repair.

A strip crown is indicated for anterior primary teeth having extensive interproximal or lingual caries, fractured teeth, malposed teeth (enamel hypoplasia), discolored teeth, and final restoration following pulpotomy or pulpectomy. But they are contraindicated in a severely decayed tooth with insufficient tooth structure, deep overbites, and in children with periodontal diseases.[5]

As light-curing resins are technique-sensitive, isolation plays an important role. To achieve this in younger and uncooperative children is almost impossible. Protemp 4^{TM} is hydrophobic in nature, with the least marginal discrepancy, and high fractural strength. Hence, Protemp 4^{TM} was the choice of material to restore primary anterior teeth with strip crown.

Filtek™ Z350 XT Universal Restorative is a nanocomposite with the combination of nanomer sized particles to nanocluster formulations that helps decrease the interstitial spacing of filler particles and dimethacrylate-based dental resins.

It exhibits a very shiny and smooth surface texture, making it almost impossible to distinguish from the actual tooth. If chipping or fracture is exhibited, the remaining restorations can be smoothed, re-contoured, or repaired with flowable composite.[6]

Fracture resistance, fracture toughness, flexural strength, and modulus of elasticity are important mechanical properties of restorative materials when used in situations where biting stress can propagate internal defects or initiate fracture.[7]

Fracture toughness is a very important characteristic of a structural material indicating the resistance of a material to crack and governed by force (N) needed to destroy a material (work of fracture).[8]

Methods and methods

42 exfoliated human teeth (maxillary central incisors) were collected from Dept of Pedodontics and preventive dentistry, A.J. Institute of dental sciences, Mangalore, and were stored in an isotonic saline solution.

Inclusion criteria

- Extracted primary maxillary central incisors
- Noncarious or Minimal caries involved.

Exclusion criteria

Grossly decayed teeth

Allocation to the groups

Total number of teeth specimens- 42

- **Group 1**: 21 teeth specimens were restored with Protemp 4™ (3M™ ESPE)
- **Group 2**: 21 teeth specimens were restored with filtek™ Z350 XT (3M™ ESPE)

Procedure

All teeth specimens were cleaned of gross debris by using ultrasonic scaler, and it was then stored in isotonic saline (Sodium chloride IP, 0.9% w/v, aculife, India) at 37°c.

Then specimens were embedded in block of self-cure acrylic resin using wax template measuring (1.5cm×1.5cm×3.5cm) (Figure1)

Figure 1: Wax template mesuring 1.5cm×1.5cm×3.5cm.

Tooth preparation

The teeth were numbered separately, and the three dimensions (buccolingual, mesiodistal and cervicoincisal) was measured by two investigators independently using a vernier caliper, divider and scale. The mean of those measurements was taken into consideration to guide the tooth preparation.

The buccolingual dimension were measured at the greatest curvature of the tooth at the cingulum region. The mesiodistal dimension were measured at the greatest dimension of the tooth mesiodistally. The cervicoinisal dimension was measured at the buccal surface from the most apical point of the cervical line to the incisal edge.

The crowns of the teeth were prepared to receive a strip crown. A TF-12 diamond bur (Mani Inc., Germany), BR-4 diamond bur (Mani Inc., Germany), and SI-48 diamond bur (Mani Inc., Germany) were used for crown preparation. Care was taken to ensure parallelism of the proximal surfaces. The teeth specimens were prepared to have a buccolingual width of 4.5 mm, a mesiodistal width of 5 mm, and a cervicoincisal length of 5 mm.

After tooth preparation, the measurements were measured by two investigators independently using a vernier caliper, divider, and scale.

Restoring tooth specimens with strip crown

Strip crowns were checked for fit on the prepared tooth and excess was trimmed off with sharp curved scissors

and vent holes were placed on the palatal surface using a small round bur, to help prevent the entrapment of air bubbles in the composite filling material.

All the prepared surfaces were coated with 37% phosphoric acid etchant gel (Scotchbond Multi-purpose Etchant, 3M ESPE, St. Paul, USA) for 15 seconds. The etchant was rinsed off, and the dentin surface was dried with gentle air spray. Then, bonding agent (Prime and Bond, Dentsply Sirona, Charlotte USA) was applied on the entire tooth surface and light-cured (GX-17 Dental LED Curing Light, Galaxy, India) for 30 seconds at 1,200 mw/cm^2.

The strip crown size A2 of the primary maxillary right central incisor (3M ESPE, St. Paul, USA) was used for both groups.

Group 1: Strip crowns were filled with protemp^{tm}4(3M ESPE, Seefeld, Germany; A2 shade) (Figure2)

Group 2: strip crowns were filled with Filtek Z350XT (3M ESPE, Seefeld, Germany; A2 shade- package (Figure3)

Figure 2: Protemp ™ 4

Figure 3:Filtek Z350XT

All filled crown forms were placed in tooth specimens. Excess soft composite resin at the margins was removed with an explorer. Group 1 was left to auto-polymerize for 5 minutes at room temperature. Group 2 was cured using visible light curing unit for 30 seconds at 1200mw/cm^2.The crowns were stripped off from the teeth' surface by giving a slit in the lingual surface with an explorer (Manipal Marketing, India). (Figure 4)

Figure 4: Restored tooth specimen

Thermocycling

The prepared tooth specimens were stored in saline (Sodium chloride IP,0.9% w/v, aculife, India) for 24 h and then subjected to thermocycling. The specimens were thermocycled 500 times between water baths held at 5 °C and 55 °C with 30 seconds of dwell time using a manual thermocycling unit (Water Bath, Hally instrument, India)

Figure 5: Cold and hot water bath

Fracture toughness using universal testing machine

The teeth were stored in isotonic saline (Sodium chloride IP,0.9% w/v, aculife, India) for 24 hours before testing for fracture toughness. The specimens were tested for fracture toughness using a universal testing machine [ZWICK/ ROELL Z020, Chennai, India,Asia (FIGURE -12)]. The force was applied at the incisal edges of the crown at a crosshead speed of 1 mm/minute with 0.5mm diameter indenter(rounded), and the force of fracture was recorded in Newton (N) in testxpert software. (Figure 6)

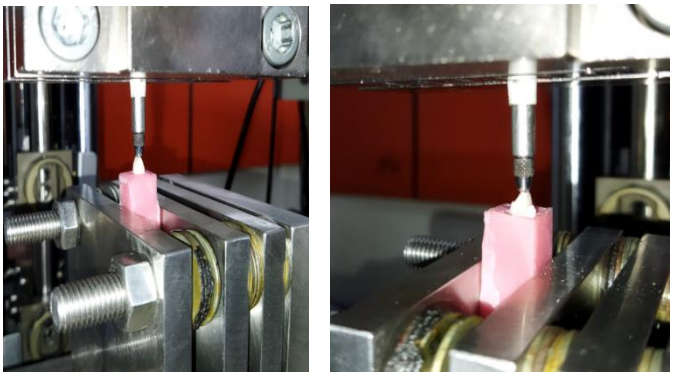


Figure 6: Rrecording fracture toughness of tooth specimen.

The results were tabulated and statistical analysis was done using SPSS (Statistical Package For Social Sciences) version 20.

Results

Data was statistically analyzed and parametric tests used was

- Statistical analysis of the data was performed using SPSS 20.0.
- ICC (Interclass correlation), to assess the consistently of measurements examined by two examiners i.e., length, mesiodistal width and buccolingual width for tooth preparation before and after tooth preparation (Table-1)
- Unpaired t test was used for comparing the fracture toughness between two groups. (Table-2)

Table 1: Inter examiner reliability between two examiners for pre and post preparation measurements by using ICC (Interclass correlation).

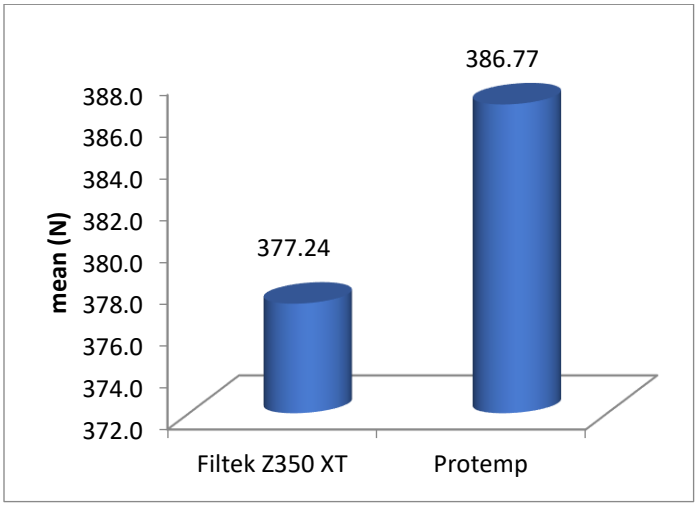
		ICC	P value
Length	Pre	0.952	P<0.001
	Post	100% agreement	
Mesio distal width	Pre	0.963	P<0.001
	Post	100% agreement	
Buccolingual width	Pre	0.848	P<0.001
	Post	100% agreement	

The inter examiner reliability of pre preparation i.e., length,mesio distal width and buccolingual width showed excellent reliability [length (chronbach alpha=0.952) , mesio distal width (chronbach alpha=0.963) and good reliability in buccolingual width (chronbach alpha=0.848)]. All post preparation measurements showed 100% agreement between two examiners. (Table 1)

The analysis shows the mean fracture toughness for protemp^{tm} 4 **(**386.77 N) was higher when compared With filtek^{tm} Z350 XT (377.24 N). This difference was not statistically significant with test value of 0.208 and p value>0.05 (i.e . 0.836) (Table- 2 and Graph 1).

Table 2: Comparison between filtek^{tm} Z350 XT and protemp^{tm} 4 using unpaired t test.

Group	N	Mean	Std. Deviation	t value	p value
Protemp™ 4	21	386.7724	116.08878	0.208	0.836
Filtek™ Z350 XT	21	377.2410	174.98843		



Graph 1: Comparison between filtek[tm] Z350 XT and protemp[tm]4.

Discussion

Deciduous teeth play a key role in phonetics, mastication, aesthetics, and maintaining space for permanent teeth.

The aesthetic repair of severely decayed anterior primary teeth is the main concern of parents and clinicians. Currently, the recommended alternative to extraction is restorative treatment. [5]

Resin composite strip crowns, open-faced stainless-steel crowns, pre-veneered stainless-steel crowns, and zirconia crowns are suggested as the treatment of choices for restoring carious primary anterior teeth.

Composite resin was first developed by Bowen in the 1960s to strengthen epoxy resin as a filler; several improvements have been made to improve its physical properties such as its resistance to abrasion, polymerization shrinkage, and bonding strength of dentin.[8]

In 1979, Webber introduced the Composite resin strip crown. It is the most commonly used procedure for restoring the primary anterior teeth. When compared to other types of anterior coronal covering, these composite strip crowns provide greater aesthetic restoration.

In most of the studies, Z100 (Restorative Extended Range Shade-Pedo Paste, 3M-ESPE Dental Products, St. Paul, Seefeld, Germany) was used with strip crowns.[9,10,11]

Success rates ranging between 70% and 100% were found in the studies done by Al-Eheideb et al[12]: Judd et al[13]: Kupietzky et al.[14]: Ram and Fuks[9]:Walia T et al[15]:Waggoner et al[10].

A high failure rate of 51% over a period of two years was seen in a study conducted by Tate et al.[16] where strip crowns were placed under general anesthesia.

The bonding interface remains the weakest area of the composite restoration. If the dentin/ adhesive interface is exposed to the oral cavity- which may lead to secondary caries, marginal discoloration, and poor marginal adaptation.[17] Chen XX et al[18] stated that in their study 1% of cases showed recurrent caries at the end of 18 months.

The number of surfaces involved also affects the retention rate of the strip crown. The failure rates are higher with four carious surfaces than in one or two carious surfaces involved (Ram and Fuks[9]).

Protemp™ 4 Temporisation Material (3M ESPE) is autopolymerizing resin. Akova et al[19] stated that Protemp 4 is hydrophobic in nature. So, it ensures minimal water uptake and, thus, reduces the plasticizing action.

Amin et al[20] evaluated and found that protemp[tm] 4 (3M™ ESPE) has the least marginal discrepancy among the provisional materials tested (Luxatemp Star, Visalys Temp, and polymethyl methacrylate).

Jo *et al.*[21]evaluated the flexural strength of interim resin materials, and concluded that Protemp 4 has higher flexural strength and hardness in comparison with other auto polymerizing and light-curing resins.

Mehrpour et al[22] evaluated the flexural strength of different interim restorative materials (tempspan, Protemp 4, Unifast III, Trim, and Revotek LC) with Protemp having high flexural strength among the other materials tested.

Pereddy MR[23] conducted a study to evaluate and compare the hardness of Protemp 4 group, Integrity group, Systemp C and B group, and Structure 2SC group. And results showed Protemp 4 showed the highest hardness.

The main drawback of auto polymerizing resin is exothermic heat liberation. Rajat R. Khajuria[24] conducted a study to compare temperature rise in the pulp chamber during the fabrication of provisional crowns using DPI tooth molding self-curing material and Protemp 4. Results showed that Protemp-4 exhibited the least temperature rise in the pulp chamber. But, the effect on primary teeth is still unknown.

According to mclaren[25], bonding of Protemp 4 was done by etching the tooth surface and followed by bonding.

3M™ Filtek™ Z350 XT is light cure resin. Bulk fill filtek[tm] Z350 XT was used in this current study which reduces the possibility of failures due to less chance of incorporating voids and a volumetric contraction with less stress on the interface. (C M P Rosatto [26])

Fabio Rizzante[27] conducted a study to assess the polymerization shrinkage, knoop microhardness, and depth of cure. Results showed filtek[tm] Z350 XT has the highest microhardness among the tested resin composites.

C J Soares[28] conducted a study to compare radiopacity and porosity using bulk-fill and incremental filling techniques to restore large mesio-occlusal-distal (MOD) cavities using Filtek Z-350XT. And results showed that bulk-fill Filtek Z-350XT demonstrated an adequate level of radiodensity and a reduced presence of voids compared with the incremental filling technique.

Rodrigo Vieira Caixeta [29] conducted a study to evaluate the bond strengths of composite restorations (Filtek Z350 XT, Filtek Z350 XT Flow, or bulk-fill X-tra fil resin) made with different filler amounts and resin composites that were photoactivated using a light-emitting diode (LED) and results showed Filtek Z350 XT had higher bond strength.

In vitro testing of the mechanical and physical properties of dental materials are indicators for success rates of treatment. Fracture resistance, fracture toughness, flexural strength, and modulus of elasticity are key mechanical qualities of restorative materials when employed in conditions where biting stress might propagate internal defects or initiate fracture.[30]

Fracture toughness is a very important characteristic of a structural material indicating the resistance of a material to crack and governed by force (N) needed to destroy a material (work of fracture).[9]

The study compared to evaluate the fracture toughness of auto-polymerizing resin (Protemp 4) and light cure resin (Filtek Z350 XT) for use in strip crowns. And results showed the mean force required to fracture strip crowns restored with Protemp 4 **(**386.77 N) was higher when compared with Filtek Z350 XT (377.24 N). But statistical analysis showed no significant difference between Protemp 4 and Filtek Z350 XT with t =0.208 and p>0.05.

Similar results were reported by K C Vignesh[11] et al on the evaluation of fracture toughness of teeth restored with Protemp 4 and Z100 used in a strip crown. In children, the average biting force for anterior teeth ranges from 140.096 N $\pm$ 6.87 N.[31] As a result, Protemp 4 and Filtek Z350 XT can be used as restorative materials in strip crowns because they exceeded the

normal masticatory force in children in the anterior region. However, further studies are needed to evaluate the flexural strength, modulus of elasticity and bond strength of Filtek Z350 XT and Protemp 4.

Conclusion

Within the limitations of this in vitro study, the mean fracture toughness for protemp[tm] 4 was higher than compared to filtek[tm] Z350 XT. However, compared to the normal masticatory force in primary anterior teeth, both materials have a strong resistance to breakage. So, auto polymerizing resin (protemp[tm] 4) can be considered as an alternative to light curing composites (filtek[tm] Z350 XT).

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