RESEARCH

Quality and leakage of perforation repair-materials: A comparison of intracoronal and retrograde techniques

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Background: The objective of this in vitro study was to evaluate the quality and leakage of repair materials when perforation sites were challenged from an orthograde or retrograde direction.

Methods: Intentional perforations were created on the mesial and distal root surfaces of the extracted human molar teeth (below the CEJ) using a diamond bur at a 45 degree angle to the long axis. Mesial perforations were repaired intracoronally using the following materials (n=15): IRM (Dentsply), amalgam (Dentsply), Dyract (Dentsply), SuperBond C&B (Sun Medical) and MTA (Dentsply). After filling the access cavities with cement, distal perforations were repaired retrogradely using the same materials. The teeth were kept at humid conditions (100%, 24hrs), the perforation sites were stained with 2%methylene blue (24hrs), sectioned and examined under a stereomicroscope at 20x and 40x magnifications and scored as extruded, insufficient or adequate in combination with the dye penetration.

Results: The data was statistically analyzed (Kruskal-Wallis and Mann-Whitney U-tests). A significant difference was found among the restoration techniques ($p<0.05$). All the materials showed less leakage when used retrogradely ($p<0.05$). Repair of the perforation through the access cavity resulted in 86% extruded or insufficient restorations with leakage. IRM restoration showed 80% and MTA showed 60% adequate restoration without leakage when applied retrogradely.

Conclusion: Repair of the perforations using the retrograde technique has significantly increased the number of the adequate restorations regardless the effect of the material factor. IRM showed the best sealing followed by MTA when applied retrogradely.

KEY WORDS

Leakage, MTA, perforation.

Root perforation is a procedural error that can occur during endodontic or restorative treatments (Thesis and Fuss 2006). Apical, furcal and lateral root perforations can cause a chronic inflammatory reaction of the periodontium and may result in irreversible attachment loss (Seltzer et al 1970, Jew et al 1982). The prognosis of treatment involving a root perforation is questionable and depends on the accessibility of the perforation, the elapsed time after the perforation and the degree of contamination (Seltzer et al 1970, Sinai et al 1989, Fuss and Trope 1996). The success rate for treatment after a lateral root perforation is lower than treatment for other type of perforations because lateral root perforations occur close to the gingival attachment site and they can be repaired by an internal or external approach (Jew et al 1982, Martin et al 1982). Another important factor is the characteristics of the materials that are used for treatment (Lee et al 1993). The repair materials that perform optimally are biocompatible, insoluble and radiopaque; they also prevent microleakage (De-Deus et al 2007). Various materials, including amalgam, composite resin, glass ionomer resin cements and mineral trioxide aggregate (MTA), have been used to restore perforations (Thesis and Fuss 2006, Fuss and Trope 1996). Several studies investigating these materials have reported that MTA has the optimal properties to manage perforations.

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The main component of MTA is calcium oxide and silicon dioxide (70% to 95% of the cement) (Torabinejad et al 1995). In addition to these components, MTA consists of tricalcium silicate, dicalcium silicate, tricalcium aluminate, tricalcium aluminoferrite, calcium sulfate and bismuth oxide (Torabinejad and Dean 1995, Coomaraswamy et al 2007). Although MTA cement is known to have poor handling characteristics, it has exhibited acceptable in vivo biologic performance when used for perforation repairs (Roberts et al 2008). Additionally, it has demonstrated low solubility and low cytotoxicity (Torabinejad et al 1997). Furthermore, MTA has the ability to induce cementogenesis; (Torabinejad et al 1997, Pitt Ford et al 1995) it permits cementoblast attachment and growth as well as the production of mineralized matrix gene and protein expression (Hakkı et al 2009).

Materials used to repair root perforations have different physical properties. Among these materials, amalgam shows insufficient marginal sealing and is found to be inadequate in generating hard tissue formation (Pitt Ford et al 1995, Frank et al 1992). Gartner et al (1992) reported that zinc oxide-eugenol (ZOE) cement Super Ethoxybenzoic Acid (EBA) has a low cytotoxic effect, releasing only 2% of eugenol while curing. However, Wu et al (1998) reported that Super EBA and amalgam showed microleakage. Glass ionomer sealers have been suggested by Wu et al (1998) for their dentin adhesive properties and mild cytotocixity. With the improvements in adhesive dentistry, resin-based materials have become an alternative for repairing root perforations. Super Bond C&B consisted of 4-methacryloloxyethyl trimhate anhydride/methyl methacrylate-tri-n-butyl borane (4-META/MMA-TBB) and MMA-based resins showed strong adhesion to root dentin (Bouillaguet et al 2003). Despite its relatively short working time (Leonard et al 1996) Super Bond C&B may be preferred due to its biocompatible properties on the tissue (Henmi et al 2003).

Compomers (polyacid-modified composite resins) are characterized by having improved physical and mechanical properties when compared with conventional glass-ionomer cements and composite resins. Compomers now combine the fluoride release of glass-ionomer cements and the mechanical properties of composite resins; however, they are reported to be cytotoxic to primary human gingival fibroblast cultures by inhibiting cell growth and proliferation (Huang et al 2002).

Extruded or inadequate restorative materials at perforation area increase the risk of treatment failure (Petersson et al 1985). Although biocompatible matrices have been used to prevent inflammation and foreign body reactions caused by extrusion, insufficient restorations may affect the healing process and may not be able to protect the tooth from microleakage (Alhadainy and Himel 1993). Therefore, the primary objective of this in vitro study was to evaluate the quality of different repair materials when perforation sites were challenged from an orthograde or retrograde direction. A dye penetration evaluation was also added to the study to test the sealing ability of the materials. The tested hypothesis was the following: there is no difference among the quality of the restorations when repair materials are applied from an orthograde or retrograde direction, and the quality of the restoration does not affect leakage.

MATERIAL AND METHODS

Eighty-seven sound, human mandibular molars that were extracted for periodontal reasons were used. The teeth were decoronated 4 mm above the cementoenamel junction (CEJ), and the roots were resected 6 mm below the furcation. Cavities were prepared at the apical part of each root using a round diamond bur (#4, Dentsply Tulsa Dental, Tulsa OK). These cavities were then restored with composite resin (Clearfil AP-X, Kuraray, Japan) using self-etch adhesive (Clearfil SE Bond, Kuraray, Japan). Standard coronal access cavities were prepared on the occlusal surface of each tooth using high-speed burs with water spray; these cavities were not restored.

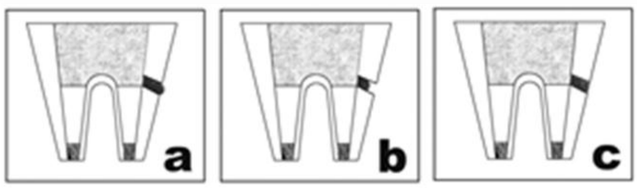

Figure 1.

Schematic representation of the scoring the restorations as: a: extruded; b: insufficiet and c: adequate

Intentional perforations were created at the mesial and distal root surfaces (below the CEJ) by using a slow-speed round bur (#2) at approximately a 45-degree angle to the long axis of each tooth under water coolant (Figure 1). This technique created a 1-mm diameter perforation site, and the dentin thickness was standardized at 1.6 mm by grinding from the internal surface of the access cavity with a diamond bur. Perforations were thoroughly irrigated with saline solution to avoid any remnants of visible debris. The prepared teeth were then inserted into a saline-soaked Oasis, a material widely used for flower arrangements, to approximate the level of the CEJ (Lee et al 1993). This set-up provided a model simulating a clinical condition in which underfilling or overfilling of the repair materials is not observable. The teeth were randomly divided into five groups (n=15). Paper points (Dentsply, Maillefer, Ballaigues, Switzerland) were used to dry the perforation area, and the perforations were repaired with the following materials according to the manufacturers' instructions:

Group 1- Intermediate restorative material (IRM; Dentsply/Caulk, Milford, DE);

Group 2- Amalgam (Dentsply/Caulk, Milford, DE);

Group 3- Dyract (Dentsply, DeTrey, Germany);

Group 4- Superbond C&B (Sun Medical, Japan);

Group 5- MTA (ProRoot; Dentsply, Tulsa Dental, OK).

A plugger was used to condense the IRM, amalgam and Super Bond C&B. Perforation sites were treated with Prime Bond NT (Dentsply, DeTrey, Germany) before injecting Dyract. A curing unit (Bluephase, Ivoclar, Vivadent, Liechtenstein) with an intensity of minimum 700 mW/cm2 was used to polymerize the material. A moist cotton pellet was used to condense MTA into the perforation sites, and a temporary filling material was gently placed to allow for the setting of MTA for 1 day before filling with a restorative material.

All of the access cavities were sealed with IRM and distal perforations were repaired externally by removing the oasis material to provide visibility. The perforations in six teeth (Group 6) were not repaired and served as positive controls; six non-perforated teeth were used as negative controls (Group 7). The teeth were stored at a temperature of 37°C and 100% humidity conditions for 24 hrs. With the exception of 1 to 2 mm around the perforation sites, the root surfaces were covered with a double layer of nail polish. The samples were then placed in 2% methylene blue for 24h, washed with tap water and separated into two bucco-lingual sections that were parallel to the long axes of the teeth. The separation occurred down the center of the perforations to expose the filled perforated site by using a low-speed handpiece. The sections were evaluated under stereomicroscope (X20-X40, Olympus SZ40, Japan). The extruded (Figure 1a), insufficient (Figure 1b) and adequate (Figure 1c) restorations were recorded and scored in combination with the dye penetration as follows:

1) Extruded restoration with leakage toward the restoration-root interface (Figure 2);

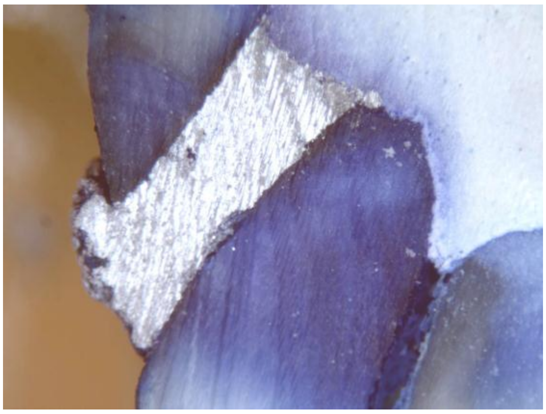

Figure 2.

Total leakage with an amalgam restoration placed orthogradely considered as score 1

2) Insufficient restoration with leakage toward the restoration-root interface (Figure 3);

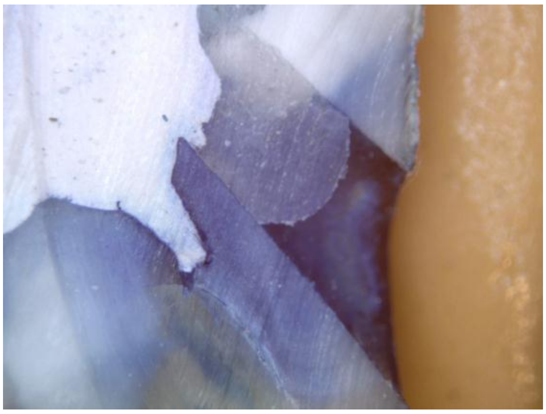

Figure 3.

Total leakage with an insufficient Super Bond C&B restoration placed orthogradely considered as Score 2

3) Extruded restoration with leakage at ½ up the restoration-root interface or whole leakage at one of the restoration-root interfaces (Figure 4);

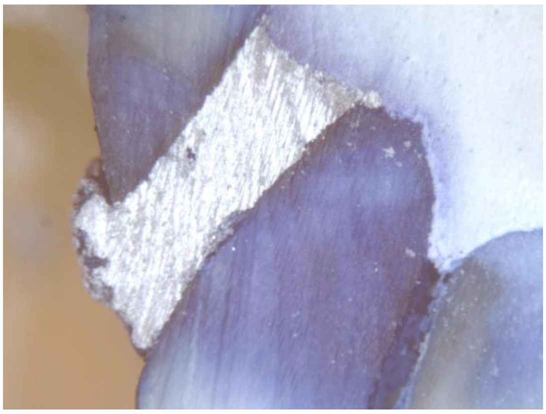

Figure 4.

Partial leakage with an extruded orthograde amalgam restoration considered as Score 3

4) Insufficient restoration with leakage at ½ up the restoration-root interface or whole leakage at one of the restoration-root interfaces (Figure 5);

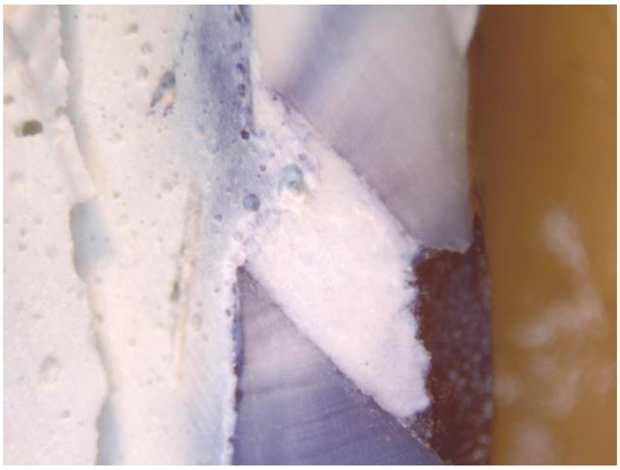

Figure 5.

Partial leakage with an isufficient MTA restoration placed orthogradely considered as Score 4

5) Adequate restoration showing leakage at ½ up the restoration-root interface or whole leakage at one of the restoration-root interfaces (Figure 6);

Figure 6.

Partial leakage with an adequate MTA restoration placed retrogradely considered as Score 5

Table 1.

The extruded, insufficient and adequate restoration scores in combination with the dye penetration (*Orthograde restoration, **Retrograde restoration)

	1		2		3		4		5		6		7	
	O	R	O	R	O	R	O	R	O	R	O	R	O	R
IRM	-	-	4	-	4	-	7	-	-	-	-	3	-	12
Amalgam	4	-	9	-	-	-	-	-	-	-	1	14	1	1
Dyract	6	-	2	1	6	2	-	3	-	-	1	8	-	1
C&B	1	1	4	2	7	3	2	1	-	-	-	3	1	5
MTA	-	-	3	-	-	-	6	3	-	-	4	3	2	9

6) Adequate restoration without leakage (Figure 7).

Figure 7.

Adequate restoration with IRM placed retrogradely considered as score 6

The distribution of the data was statistically analyzed using Kruskal-Wallis and Mann-Whitney U-tests.

RESULTS

All of the specimens in the positive control group showed dye penetration whereas any of the negative control group specimens showed dye leakage (Table 1). The stereomicroscope evaluations indicated that the IRM group, amalgam group, Dyract group, Super Bond C&B group and MTA group showed 100%, 86.6%, 93.3%, 93.3% and 60%, respectively, of extruded or insufficient restorations when the perforations were restored from an orthograde direction through an access cavity. A significant difference was found among the leakage scores of the orthograde and retrograde restorations ($p<0.000$). IRM and amalgam resulted in 100% adequate restorations when applied from the retrograde direction; Dyract, Super Bond C&B and MTA showed 60%, 53.4% and 80%, respectively, of adequate restorations when applied from the retrograde direction.

IRM, Super Bond C&B and MTA showed similar leakage scores when the perforations were restored from the orthograde direction ($p>0.05$). Amalgam and Dyract also showed similar leakage scores when restored from the orthograde direction; however, amalgam showed a mostly extruded (Score 2), and Dyract showed mostly insufficient restorations (Scores 1 and 3). Leakage in the MTA group was mostly due to insufficient restorations when the perforation sites were challenged from the orthograde direction (Scores 2 and 4). Repair of the perforations from the orthograde direction resulted in 86% being extruded or insufficient restorations with dye penetration; Repair of the perforations from the retrograde direction resulted in 21.3% (Score 1-4). All of the materials showed lower leakage when used from the retrograde direction ($p<0.05$).

DISCUSSION

In the present study, lateral perforations were made in the mandibular molar teeth below the CEJ. This location simulated actual clinical conditions where perforations occur during access cavity preparation or when searching for root canals. The critical problem in perforation restoration is of the restoration-root interfaces placing the repair material, especially when the perforations are large (Balla et al. 1991). Extrusion of the filling material is reported as one of the potential problems (Benenati et al 1986). Repair may be complicated when there is extrusion into the periodontal ligament space using the orthograde technique because control of the repair material is difficult (Petersson et al 1985). Holland et al (2001) evaluated histomorphologic parameters in laterally perforated and restored dog teeth and reported that the filling quality of the perforation can affect healing. In the present study, the clinical situation was simulated using a saline-soaked oasis to condense the materials into the defect (Lee et al 1993). The results show that the percentage of extruded or insufficient restorations is increased when the perforations are repaired from an orthograde direction. These results indicate that clinicians should be aware of extruding material during the restoration of perforations from an orthograde direction; however, a poor condensation should also be avoided so as not to cause insufficient restorations. The percentage of adequate restorations increased when the perforations were restored from the retrograde direction (46.6% to 100%). Therefore, we reject the main hypothesis of this study that states there is no difference among the quality of the restorations when repair materials are applied from the orthograde or retrograde direction.

IRM is reinforced zinc oxide-eugenol cement, and it is usually used in furcation repair or retrograde apical fillings (Frank and Weine 1973, Dorn and Gartner 1990, Blaney et al 1981). In this study, IRM showed the least dye leakage, followed by MTA, when applied from the retrograde direction. When the perforations were restored from the orthograde direction, IRM and MTA showed similar leakage. Blaney et al (1981) and Lee et al (1993) reported that MTA shows better sealing than IRM. These authors treated the perforated teeth from an orthograde approach; they reported that the mineral oxides in MTA reacted with the water from the surrounding tissues and activated a chemical reaction. MTA generates superficial and interfacial hydroxyapatite (HAp) precipitate when in contact with dentin in the presence of liquid media, which has been characterized as similar in composition to hydroxyapatite (Sarkar et al 2005, Tay et al 2007). When perforations were repaired with MTA, significantly less leakage was observed using both dye and bacteria leakage methods when compared with amalgam, IRM, ZOE and Super EBA (Wu et al 1998, Ferraz et al 1999, Wolanek et al 2001). Further studies have reported that MTA is superior to amalgam, IRM and Super-EBA in providing satisfactory sealing (Torabinejad and Pitt Ford 1996, Nakata et al 1998, Weldon et al 2002). A long setting time, difficult handling characteristics and porosity after setting may affect the performance of MTA (Torabinejad et al 1995, Kogan et al 2006). Hemorrhage control is another factor that can affect the performance of repair material. Dry conditions and visibility simulated the surgical treatment conditions; factors such as contamination of the dentin surface due to excessive moisture, bonding materials and remaining air voids, which can affect the bonding of IRM, MTA and other test materials, were eliminated in the retrograde filling groups in this study (Walshaw and McComb 1996). IRM showed the least leakage followed by MTA. MTA groups generally showed insufficient restorations when they were applied from an orthograde direction (60%) and had 86.6% leakage. The number of adequate restorations increased (80%) when they were applied from a retrograde direction and had 40% leakage. Therefore, we can state the following: if dry conditions and visibility can be provided in clinical conditions and MTA can be applied from a retrograde direction, both the quality of the restoration and the sealing performance can be improved.

Super Bond C&B is a self-cured methyl methacrylate/polymethyl methacrylate system that does not contain hard glass filler particles, and it is both a bonding agent and resin cement. The application process of the material remains technically sensitive. Super Bond C&B requires pretreatment of the dentin with a conditioning solution for 10 s. This pretreatment is followed by water rinsing, drying and a minimum of 10 minutes of setting time. Although some perforations are treated easily, it may be difficult to apply this material in deep and oblique defects such as those simulated in this study. Hence, stereomicroscope evaluations show 100% extruded or insufficient restorations with Super Bond C&B when it was applied internally through the access cavity. The percentage of the adequate restorations increased when applied from a retrograde direction (53.3%).

Histological studies and periodontal healing scores have shown good results with methyl methacrylate/polymethyl methacrylate systems, (Maeda et al 1999, Sugaya et al 2001) and C&B Metabond has been shown to prevent microleakage throughout each experimental time period in a previous longitudinal in vitro study; (Weldon et al 2002) however, according to our study results, Super Bond C&B should not be used when applying from an orthograde direction because of its technique sensitivity.

Lee et al (1993) reported that the overfilling or underfilling of material does not affect the sealing ability. In this study, the sealing ability was evaluated by a dye penetration test. Dye penetration using 0.2-2.0% methylene blue is the most commonly used technique in leakage studies because of its easy manipulation and high degree of staining as well as the fact that it has a lower molecular weight than that of bacterial toxins (Wu and Wesselink 1993,Verissimo and Do Vale 2006). Therefore, 2% methylene blue was used. More dye penetration was observed in samples when they were restored from an orthograde direction through an endodontic access. This supports findings from a previous study by Hamad et al (2006) and Wu et al (1993) reported a significant discoloration of 1% methylene blue after 24 hours of contact with MTA-filled roots and concluded that the calcium oxide contained in MTA, with water, may form $Ca(OH)_2$ that decolors methylene blue. However, Hamad et al (2006) reported similar leakage with white and gray proRoot MTA. The authors explained that this leakage occurred due to a series of alterations in the structure of MTA. The evaluation of sealing ability of materials was not the primary aim of the present study; however, we do have to reject the second hypothesis of the study in part: the quality of the restoration does not affect the leakage. Extruded and insufficient restorations show more leakage in the orthograde groups when compared to retrograde filling groups, whereas adequate restorations show more leakage than the extruded or insufficient restorations in the retrograde groups (Score 6). The classical dye penetration test was done in this study. Although linear measurement is generally used to evaluate dye penetration, it is not reliable in this study because of the high percentage of extruded and insufficient restorations (Youngson et al 1990). Instead, a scoring system was used to evaluate both the quality of the restoration and the degree of dye penetration. Regardless of the material used, we found significantly more leakage when the materials were used from an orthograde direction. This finding supports the study of Hamad et al (2006).

CONCLUSION

Within the limitations of this in vitro study, the results are as follows:

1) The percentage of inadequate restorations increased when using the orthograde restoration technique;

2) A significant difference was found among the leakage scores of the orthograde and retrograde restorations;

3) When applied from a retrograde direction, IRM demonstrated the best results in adequate filling, without leakage, followed by MTA.

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Perforasyon tamir materyallerinin sızıntı ve kalitesi: İntrakoronal ve retrograd tekniklerin karşılaştırılması

Amaç: Bu in vitro çalışmanın amacı, perforasyon tamir materyallerinin, perforasyon bölgesine ortograd ya da retrograd yerleştirildiğinde, sızıntı ve kalitesini değerlendirmektir.

Gereç ve Yöntemler: Çekilmiş insan molar dişlerin mesial ve distal kök yüzeylerinde, dişin uzun aksına 45 derecelik açıyla elmas bir frez ile kasten perforasyonlar oluşturuldu. Mesial perforasyonlar intrakoronal olarak şu materyaller kullanılarak tamir edildi: IRM (Dentsply), amalgam (Dentsply), Dyract (Dentsply), SuperBond C&B (Sun Medical) and MTA (Dentsply). Siman ile giriş kavitesi doldurulduktan sonra distal perforasyonlar aynı materyaller ile retrograd olarak tamir edildi. Dişler %100 nemli ortamda 24 saat saklandı. Perforasyon bölgeleri 24 saat %2'lik metilen mavisinde bekletildi. Dişler kesilerek, 20x ve 40x büyütme ile stereomikroskop altında incelendi ve boya penetrasyonuna göre taşmış, yeterli ve yetersiz olarak skorlandı.

Bulgular: Veriler Kruskal-Wallis ve Mann-Whitney U-testleri ile analiz edildi. Restorasyon teknikleri arasında önemli derecede fark bulundu ($p<0.05$). Tüm materyallerde retrograd teknik kullanıldığı zaman daha az sızıntı gözlendi ($p<0.05$). Giriş kavitesi boyunca perforasyonun tamiri, %86 taşmış ya da yetersiz bulundu. Retrograd olarak uygulandığı zaman IRM %80, MTA %60 oranında sızıntı olmadan yeterli bulundu.

Sonuç: Retrograd teknik kullanarak perforasyonların tamiri, kullanılan materyalin etkisi olmaksızın yeterli restorasyonun sayısı önemli derecede arttı. IRM retrograd uygulandığı zaman MTA'yı takiben en iyi kapamayı sağladı.

ANAHTAR KELİMELER

MTA, perforasyon, sızıntı

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