Retrograde approaches in endodontic therapy

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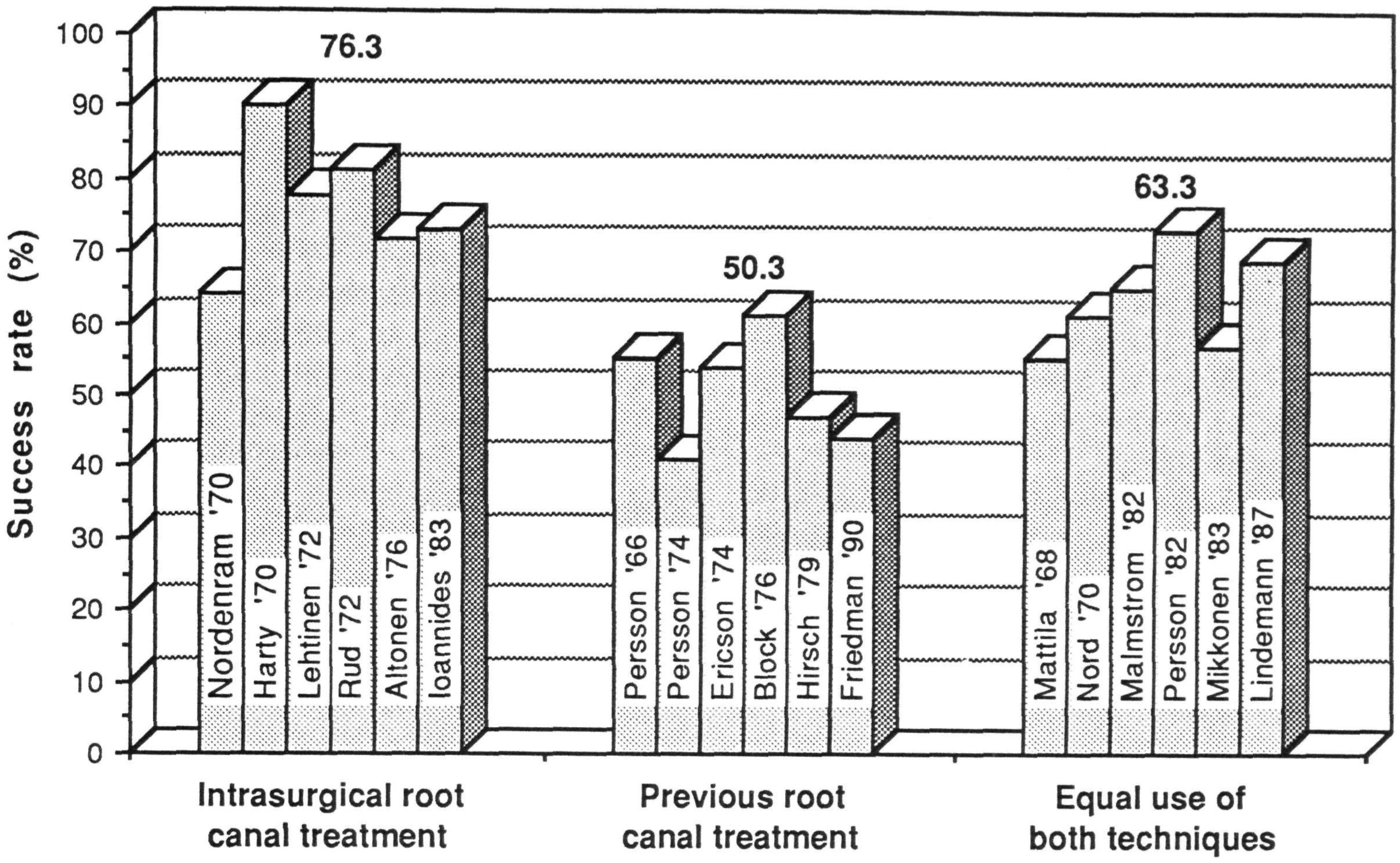

Fig. 1. Graphic representation of the success rate of apical surgery as reported in 36 studies. The prognosis is related to the surgical and endodontic technique, and the studies are grouped accordingly. The mean success rate of each group is presented above the columns. Studies in which orthograde endodontic treatment was performed in conjunction with surgery demonstrate the highest success rate.

composite resins to dentin improves their sealing ability (27, 28), which may be advantageous to the application of composite resins as retrograde filling materials. However, the efficacy of the dentin bonding systems for composite resins is reduced by exposure of the prepared dentin surface to moisture (29). Depending on the type of material used, composite resins may be applied as retrograde fillings by a plastic instrument or by a syringe. Light-cured composite resins offer the advantage that their setting can be controlled (30).

Zinc oxide eugenol cement – The manipulation of zinc oxide eugenol cement is simple, making it a convenient retrograde filling material which "requires considerably less skill in handling and control than does amalgam" (5). Plain zinc oxide eugenol cement may be used as a retrograde filling material, but it is absorbable by vital tissue (1). Consequently, the use of reinforced zinc oxide eugenol cement has been suggested as an alternative (30–36). Zinc oxide eugenol reinforced with methyl methacrylate polymer, e.g. IRM (Caulk, Milford, DE) is being used as a retrograde filling material (31–33), but it may still be resorbable (30, 34). EBA cement, a composition of zinc oxide and aluminum oxide mixed with o-ethoxybenzoic acid and eugenol (30, 32–37), is the strongest and least soluble of all zinc oxide eugenol cement formulations (37, 38). EBA cement is claimed to be nonresorbable when placed in vital tissue (34) and it is capable of adhering to dentin (34). The setting time of EBA cement cannot be controlled predictably (32), and voids may form during placement of the material (35).

Glass ionomer cement – Theoretically, the advantage of using glass ionomer cement as a retrograde filling material is its chemical bond with dentin, which allegedly results in a superior seal (39–41). However, the setting reaction of glass ionomer cement is adversely affected by hydration and dehydration (42), both of which are difficult to control clinically. As a result, the suitability of glass ionomer cement as a retrograde filling material is questioned (39). Glass ionomer cements of the latest generation are less affected by moisture (43), and may be better suited for clinical use as retrograde filling materials than former glass ionomer cements. Glass ionomer cement is sticky, and its application as a retrograde filling is difficult (44). Application is usually facilitated by use of a syringe.

Polycarboxylate cement – Zinc polycarboxylate cement consists of zinc oxide, magnesium oxide and possibly aluminum oxide, mixed with a water solution of polyacrylic acid. It is used in dental procedures both as a luting cement and a restorative material, because of its property of adherence to tooth substance by chelating to calcium (38). Because of the same reason it has been considered by some as a potential retrograde filling material

(45–47). However, the adherence of polycarboxylate cement to dentin is lesser than to enamel (38). Furthermore, the bond to dentin is adversely affected by moisture and protein contamination, such as contact with blood or saliva (38). Polycarboxylate cement is hardly soluble in water (38), adding to its theoretical advantages as a retrograde filling material (46). In a vital tissue, however, it may be partly absorbed (38). The application of polycarboxylate cement is difficult as a result of its viscosity, and because of the acceleration of its setting reaction in a warm environment (38).

Cavit – Cavit (Premier Dental Products, Norristown, PA) is a synthetic, zinc oxide-based temporary filling material. Over the years it has been considered for use as a retrograde filling material primarily because of its easy application, which does not require any manipulation or mixing (48–50). Cavit is a hygroscopic material which expands linearily as a result of water absorption during setting (51). Consequently, its adaptation to the cavity walls is expected to be good, but possibly a minimum thickness of the material is required for an optimal seal to be obtained (52). Inasmuch as the setting of Cavit is enhanced by tissue fluids, in vivo it is soluble and may be quickly disintegrated (51).

Other materials – Gold foil (53), Teflon (31), poly-Hema and Hydron (54), zinc-phosphate cement (47), and cyanoacrylate cement (55, 56), have all been mentioned as potential retrograde filling materials. Each one of these materials is suggested to have advantages that would merit its clinical use in this capacity, but their mention in the literature in relation to retrograde filling is sporadic. Consequently, these materials cannot be compared conclusively with the formerly listed retrograde filling materials. Some reports indicate that other materials may have to be considered as retrograde filling materials in the future. These materials are the innert and non-corrosive titanium screws (57), and biomaterials which may be fused to dentin by laser, such as enamel and dentin chips (58) or syntered hydroxyapatite (59).

Gutta-percha – Gutta-percha is the material of choice when retrograde endodontic treatment is performed (1). As a retrograde filling, gutta-percha is used in conjunction with chloropercha (11), or in a thermoplasticized form (60, 61), so that the retrograde filling may be adapted to the cavity walls. However, it is the orthograde gutta-percha root canal obturation that is frequently associated with apical surgery by being burnished after apicoectomy with either a hot or cold burnisher. This procedure is an attempt to obtain an improved apical seal of the root canal without performing a retrograde filling. Although this is not a retrograde filling technique as such, often its efficacy has been compared with that of retrograde filling with some of the formentioned materials (62–69).

Evaluation of retrograde filling materials

The evaluation of the suitability of potential retrograde filling materials for their intended use has been the purpose of numerous studies. The investigated aspects of the materials are mainly their sealing ability, marginal adaptation, and biocompatibility, as well as their clinical efficacy.

Sealability

Comparing the sealing ability of retrograde filling materials by testing leakage has been a common evaluation method, utilizing such tracers as dyes (22, 24, 28, 30–32, 35, 39, 44, 45, 56, 57, 60–65, 69–72), radionuclides (23, 36, 46, 47), pressurized liquid (73), electrolytes (25, 74), and bacteria (54, 57). The results of the studies utilizing those various leakage techniques are not comparable (74, 75).

Most leakage studies were performed in vitro without exposing the retrograde filling materials to the influence of tissue and tissue fluids. The leakage behavior of retrograde fillings performed with various materials differs in a dry and a wet environment (72, 76). Polycarboxylate cement, Teflon, IRM, EBA cement (72) and glass ionomer cement (76), all sealed better when tested "dry" than when tested "wet". Conversely, amalgam sealed better in a "wet" experiment than in a "dry" one (72). These results demonstrate the distortion that is introduced by comparing these particular retrograde filling materials in a dry environment, as was the case in many sealability studies (24, 31, 32, 35, 36, 47, 69). Another limitation of in vitro sealability studies is the short time span in which they are usually performed. The margins of amalgam fillings are progressively sealed by corrosion products (77), resulting in a gradually improved seal (23, 46). In short term experiments this is not effected (46, 77), and neither is the possible deterioration of materials like Cavit (48–50), polycarboxylate cement (38, 46), zinc oxide eugenol or glass ionomer cement.

Clearly, the main limitation of in vitro leakage studies is their inadequate simulation of operative restrictions and of the clinical environment. The methodology of sealability studies has been improved by subcutaneously implanting roots in which retrograde fillings had been placed extraorally (23). To further improve the methodology several researchers performed retrograde fillings in animal teeth in vivo (22, 46, 62, 71). In both cases the retrograde filling materials had been allowed to interact with vital tissue for months before the teeth were removed and leakage was tested. In one study

(46) the leakage of retrograde fillings performed with various materials was compared under these experimental conditions, and also in a 48-hour in vitro experiment. The leakage of the retrograde fillings performed in vivo varied from the leakage of the retrograde fillings performed in vitro with the same materials (46). This demonstrated discrepancy further undermines the validity of the in vitro leakage investigations.

In addition to the limitation of sealability studies in simulating the clinical aspects of retrograde filling, also the methodology of testing leakage is disputed. Some researchers conclude that to obtain reliable results in dye leakage studies the air must be evacuated from the specimens before leakage is tested (78, 79). This technique, however, is not commonly applied in sealability studies of retrograde filling materials. Another disputed issue is the molecular size of the tracers used for recording leakage. Small tracers are often used as the worst possible test (47) so as to demonstrate minute differences in leakage. But, being smaller than the irritants they are supposed to simulate, the validity of too small tracers is doubtful (80). In this respect it is suggested that the only clinically significant leakage may be that of large molecules, comparable in size to bacteria or to bacterial toxins (80). For example, the widely utilized tracer methylene blue dye is of small molecular weight, and it was shown to readily penetrate into gaps that are impenetrable to bacteria-sized molecules (80).

The frequent contradictions in the results of the sealability studies are demonstrated in Table 1, accentuating their limitations. However, when the information in all the studies is considered on an accumulative basis it appears that some materials seal better than others (Fig. 2). These materials are: amalgam used in conjunction with cavity varnish, composite resin used with or without dentin bonding, and glass ionomer cement. Based upon the studies in which the sealability of these materials was tested in vivo, the following conclusions emerge. Amalgam retrograde fillings, placed without cavity varnish, permitted less leakage than retrograde fillings performed of polycarboxylate cement or Cavit, both of which suffered marginal disintegration (46). Retrograde fillings performed with zinc-free amalgam demonstrated less leakage after 22 months than

Table 1. The summarized results of sealability studies. The comparison results are coded as the following: 2 – best, 1 – mediocre, 0 – worst.

Author	year	AM*	AM	GI	CR	GP	IRM	EBA	PCC	CAV	other
In vitro studies											
Barry	1976		2						0		
Delivanis	1978		1						0	2	
Kos	1982		1		2	0					
Abdal	1982	2	0	2	2	1					
Dalal	1983		2	1		0					
Szeremeta-Browar	1984		0			1		2			
Shani	1984		0		2				1	1	
Mattison	1985	2	0								
Luomanen	1985	0									2 TS
Vertucci	1986	2	1			0					
Smee	1987		0		2	0	1				2 TF
McDonald	1987		0		2	0				0	
Beltes	1988	2		1		0		2			
Zetterqvist	1988		0	2		1					
Negm	1988		2		0	0					
Barkhordar	1988	1	0			0					2 CA
Schwartz	1988	0		2							
Tuggle	1989	2	1			0		1			
Barkhordar	1989	1	0	2							
Shaw	1989	2	1			0					
Bondra	1989	0					2	2			
Thirawat	1989	0		2	2			0			
McDonald	1990	0	1		2	0					
Fournier	1990	1					0	2			
In vivo studies											
Delivanis	1978		2						1	0	
Bramwell	1986		2			2					
Tronstad	1983	2	0								
Friedman	1990	2		1	0						

AM* Amalgam with varnish; AM Amalgam; GI Glass ionomer cement; CR Composite resin; GP Gutta-percha; EBA EBA cement; PCC Polycarboxylate cement; CAV cavit; TS Titanium screws; TF Teflon; CA Cyanoacrylate cement.

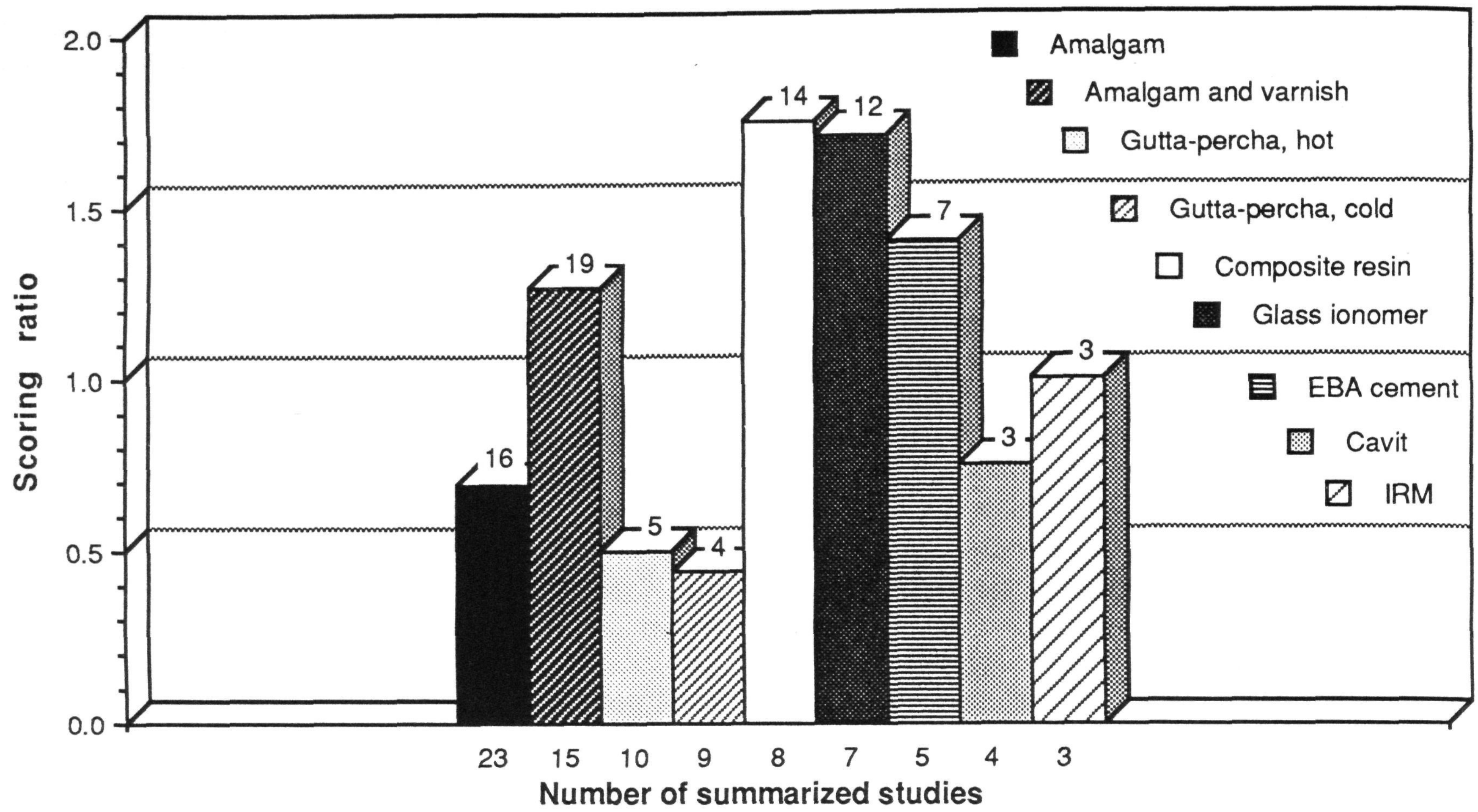

Fig. 2. Graphic summary of the combined results of 29 sealability studies of retrograde filling materials. The materials were given scores according to how they compared in each study; the best scored 2, the mediocre scored 1, and the worst scored 0. The total scores, presented on top of the columns, were obtained by summing the scores of all the studies in which each of the materials was compared. The figures at the bottom indicate the number of studies evaluating each material. The columns represent the ratio between the total score and the number of relevant studies, indicating the overall performance of the materials in the studies.

fillings with zinc-containing amalgam (22). In that study, both amalgam types were used without application of cavity varnish. A copper-containing spherical amalgam was superior to silver amalgam and dispersed phase amalgam (23). Regardless of the type of amalgam used, less leakage occurred when varnish was applied to the retrograde cavity walls before placement of the retrograde filling (23). Finally, when the sealability of retrograde fillings performed in vivo with either amalgam with cavity varnish, dentin-bonded composite resin or glass ionomer cement were compared by dye leakage, amalgam with varnish demonstrated the better seal, although the differences were not statistically significant (71).

Marginal adaptation

The marginal adaptation of retrograde fillings, observed with the scanning electron microscope, assumedly reflects their sealing potential (66). The correlation between these two parameters was demonstrated in retrograde fillings in vitro (26), but recently it was challenged (73). Generally, the use of the scanning electron microscope in these studies has certain limitations. Because the preparation of a specimen for scanning electron microscopy involves drying, cracks may form in the margins of the retrograde fillings, which may be interpreted as marginal gaps. To avoid such artifacts replicas of the specimens' surfaces are prepared, and actually observed under the microscope instead of the original specimens (26). Furthermore, the marginal adaptation of a retrograde filling may not be uniform all around its circumference, and it differs between the inner, coronal, and the outer, apical, surfaces of the filling (26). Because only one surface is observed in scanning electron microscopy, it is possible that the marginal gaps observed on that surface are not representative of the marginal adaptation elsewhere around the retrograde filling. Despite these limitations, there appears to be a consensus that amalgam retrograde fillings have the largest marginal gaps of all retrograde filling materials, ranging from 10–150 μm (26, 66, 73). These gaps are believed to be sealed initially by the cavity varnish, and later by corrosion products (23, 77). Other retrograde filling materials demonstrated marginal adaptation of comparable quality, with the exception of composite resins, which demonstrate minimal marginal gaps, measured in one study to be 1 μm wide (26).

Biocompatibility

The methodology of testing biocompatibility of retrograde filling materials is similar to that of testing other dental materials, as summarized by the FDI Commission on Dental Materials (81). Frequently performed studies include in vitro cytotoxicity tests in cell or tissue cultures (82–87) and subcutaneous or bone implant tests (88–92). The interpretation and correlation of results obtained in such studies is problematic (93). Usage tests (22, 40, 67, 68) observe histologically the specific interaction between retrograde fillings and the periapical tissues, and they are therefore clinically relevant. Despite their limitations, however, all the biocompatibility screening tests are a simple and essential way to indicate which materials to discard and which to test further (82).

In summary of the information regarding the biocompatibility of retrograde filling materials most of the commonly discussed materials have been confirmed to the biocompatible, including various zinc oxide eugenol formulations (34, 85), glass ionomer cement (40, 68, 87, 89–91), polycarboxylate cement (92) and gutta-percha (67, 68). In contrast, the biocompatibility of a composite resin (Restodent; Lee Pharmaceuticals, South El Monte, CA) has been questioned (83, 84). Methyl cyanoacrylate cement (55) is not biocompatible, whereas the biocompatibility of isobutyl cyanoacrylate cement is acceptable (56). Results of studies on the toxicity of Cavit are conflicting, with observations of both high toxicity (85, 88) and no toxicity (83). Amalgam corrosion products were also found to be toxic (86), but the good biocompatibility of the currently used amalgam types has been confirmed in several usage tests (22, 40, 67).

Clinical studies

After the biocompatibility of retrograde filling materials is ascertained, a clinical comparison appears to be the most valid method for evaluating their efficacy. Nordenram (55) studied the success rate in 31 teeth in which retrograde fillings were performed with Biobond, a methyl cyanoacrylate based material. Radiographic and clinical criteria were used during a 6–24 month observation period. The success rate with Biobond was similar to that observed in 35 teeth in which gutta-percha was used as the retrograde filling material. The success rate in both groups was lower than that found in 34 teeth in which no retrograde fillings were placed. In a prospective study Persson et al. (49) and Finne et al. (50) have examined 220 teeth in which retrograde fillings had been performed with amalgam and Cavit, one and three years after surgery, respectively. Based on radiographic and clinical criteria, they found better treatment success after retrograde filling with amalgam than with Cavit (49, 50). Their radiographs also demonstrate that about 25% of the retrograde fillings with Cavit have been considerably dissolved (50). Dalal and Gohil (69) compared the results of apical surgery in 40 teeth, six months after retrograde filling had been performed with either amalgam, glass ionomer cement or gutta-percha. Using radiographic and clinical criteria for the evaluation they claim that performing retrograde fillings with amalgam has been significantly more successful than using glass ionomer cement or gutta-percha (69). Rud et al. (94) compared radiographically the success rate of apical surgery using Retroplast, a dentin-bonded composite resin, and amalgam as retrograde fillings. In their study the composite resin had been used as a dentin-bonded coating over the resected root surface, which was scooped to contain the material without preparation of a retrograde cavity (94). After an observation period of six to twelve months, the success rate using the composite resin in 388 roots was 74%. Comparing that result with the success rate they found some 15 years earlier using amalgam for retrograde filling, these authors conclude that the composite resin is superior to amalgam (94). Despite the encouraging results, the authors caution against the toxicity of the composite resin if not used strictly dry, and they mention that in two patients severe osteitis evolved after using Retroplast (94). Recently, Dorn and Gartner (33) reported on a retrospective clinical comparison of amalgam, IRM and EBA cement used as retrograde filling materials. Based on a six-month radiographic observation, they compared the success rate in 294 teeth retrograde-filled with amalgam, with that of 129 teeth and 65 teeth in which IRM and EBA cement had been used, respectively. The clinical procedures had been performed by several operators in each one of two different clinics. They conclude that both EBA cement and IRM significantly improve the success rate as compared to amalgam when used as retrograde fillings in apical surgery (33). In all those studies amalgam was used without cavity varnish.

These clinical studies reflect the operative difficulties associated with retrograde filling, as well as the long term behavior of the retrograde filling materials in the periapical environment. However, because the prognosis of apical surgery is affected by numerous clinical factors (9, 12, 16), the influence of factors other than the efficacy of the retrograde fillings on the results of these studies may not be disregarded. Consequently, the differences in the success rate observed in clinical comparisons may be related reliably to differences in the efficacy of the retrograde fillings compared only by using large populations, firm evaluation criteria, and sufficient observation periods. In addition, as much standartization as possible regarding all the other clinical factors is required. Using this as a guideline for evaluating the forementioned clinical comparisons of retrograde filling materials it is concluded that all these studies, except that of Persson et al. (49) and Finne et al. (50), are compromised by methodological shortcomings which render the clinical value of their conclusions questionable. Also, because of the use in all these studies of amalgam without cavity varnish, their results cannot be extrapolated to indicate the clinical efficacy of retrograde filling using amalgam in conjunction with cavity varnish.

In an attempt to overcome some of the requirements and limitations of comparing retrograde filling materials in patients, Friedman et al. (95) performed such a comparison in dogs. After infecting the teeth, they performed apical surgery and retrograde filling with either amalgam with cavity varnish, dentin-bonded composite resin or glass ionomer cement. Based on a six-month radiographic observation of healing, a significantly higher success rate was reported after retrograde filling with amalgam and varnish than after using the composite resin. The glass ionomer cement was inferior to the amalgam and superior to the composite resin, but in both comparisons the differences were not statistically significant (95).

In summary of the clinical studies, they are too few and diverse to be conclusive when all are considered together. It appears that all of amalgam with varnish, glass ionomer cement, dentin-bonded composite resin, IRM and EBA cement may be used successfully as retrograde filling materials. Therefore, future clinical studies will have to focus on comparing these materials with each other.

Mechanical aspects of retrograde filling

Having chosen the retrograde filling material it must be remembered that also the retrograde cavity design is important for successful retrograde filling. Commonly, a simple cavity is prepared by enlarging the canal orifice, often referred to as a Class I preparation, which may be elongated to include two canal orifices and a connecting isthmus (20). The preparation should be extended as far coronally as it is clinically feasible, to improve the seal (25). In addition, by extending the retrograde cavity coronally, dentinal tubuli which may communicate between the root canal and the bevelled root surface are blocked from within (63, 96). With a restricted access an alternative, slot type, cavity is prepared from the buccal aspect of the root tip, into the buccal and the bevelled root surfaces (20). The disadvantages of this design are the increased dependence on the marginal seal of the retrograde filling, and the enlarged interface between the retrograde filling material and the periapical tissues.

The retrograde cavity should include preparation of retention form if the retrograde filling material to be used does not adhere to dentin. Retrograde filling materials capable of adhering to dentin may require less machanical retention than other materials (34, 68). Furthermore, in two recent studies, composite resins were used as retrograde filling materials being bonded onto the bevelled root surface without cavity preparation (29, 94). In both these studies the results obtained with this technique compared favourably with the results obtained with conventional retrograde filling techniques.

Retrograde endodontic treatment

Even when performed under the best conditions and with suitable materials, retrograde filling of the root canal cannot be considered a substitute for a thorough treatment of the entire root canal. "Because success in nonsurgical endodontics is based on the principles of thorough debridement and complete obturation of the root canal system, it is logical not to ignore or compromise these principles for teeth requiring endodontic surgery" (97). Therefore, when the coronal access to the root canal is obstructed, it is appropriate to attempt treatment of the root canal through the apical access rather than just place a retrograde filling (1). Cleansing and shaping of the root canal is performed with endodontic instruments, which are modified so as to permit their entry into the root canal through the restrictive, surgical access (1, 97–99). After the root canal is prepared, it is obturated with gutta-percha (1, 97–99). Various clinicians used different names to describe this procedure, such as "surgical endodontic retreatment" and "retrograde root canal treatment" (98), "retrograde instrumentation and obturation" (97), or "retrograde gutta-percha root filling" (99), but it appears that "retrograde endodontic treatment" is a suitable name.

Clearly, the advantage of retrograde endodontic treatment over retrograde filling is the debridement of the root canal (97, 98), and its prognosis should be expected to be better than that of retrograde filling. Clinical reports of retrograde endodontic treatment have been encouraging, reporting higher success rates than most studies in which retrograde filling was performed (98, 99). Technically, however, retrograde endodontic treatment is critically dependent on accessibility, and it requires specific armamentarium (97–99). Because of these technical difficulties retrograde endodontic treatment is not practiced widely despite of its obvious advantages. It appears that the universal acceptance of retrograde endodontic treatment will depend on the emphasis it will receive in endodontic education programs, as well as on the ability to demonstrate its clinical advantages over retrograde filling in comparative studies.

Summary and conclusions

Properly performed, with suitable materials, retrograde filling is a clinically valuable procedure promoting the prognosis of apical surgery, particularly when orthograde obturation is not performed in conjunction with surgery. Despite its clinical value, retrograde filling should be considered second alternative to retrograde endodontic treatment. The choice of retrograde filling material is based on experimental data. Clinical evaluation and experiments performed in vivo are more relevant than studies performed in vitro. The most valid evaluations would appear to be long term prospective clinical studies of large populations. Such evaluations, however, are too few to be conclusive. Animal studies are a valuable adjunct to the clinical evaluation of retrograde filling materials. Considering all the reviewed information it is concluded that at present amalgam, used in conjunction with varnish, is the retrograde filling material of choice. Nevertheless, in some countries the use of amalgam is prohibited and efforts must continue to select appropriate alternatives for amalgam as a retrograde filling material.

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