



Glass ionomer cements

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Abstract

Glass ionomer cements have been used in pediatric restorative dentistry for 20 years. Their usefulness in pediatric restorative dentistry is preferential relative to other materials because of their fluoride release, chemical adhesion to tooth structure, and availability to use in a variety of clinical scenarios. This paper reviews the use of glass ionomer materials in pediatric restorative dentistry. The paper provides a look at glass ionomer cements' use as sealants and restorative materials and examines glass ionomers as adhesives, as a stand-alone material and in the sandwich technique. This paper also provides a useful guide to connecting to other references regarding specific aspects of glass ionomers in children. (*Pediatr Dent.* 2002;24:430-438)

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This paper reports on the position of the consensus conference regarding the clinical use of glass ionomer materials in children. In comparison with other materials used in clinical dentistry, there is no better example of a material that is preferentially useful in consideration of pediatric restorative dentistry than glass ionomers. These versatile materials, presented in a variety of formulations designed for particular clinical indications, present unique opportunities to accomplish a variety of clinical objectives simultaneously.

In thinking of restorative objectives for children, one must consider several general categorical objectives. Sealing the cavity, preventing further tooth destruction, rendering the tooth and the tooth-restoration interface caries resistant, and ease of use in a clinical scenario must be included. In addition, the material selected for the procedure must endure the grueling environment of the mouth for the period in which it is intended to be effective. As discussed in the literature review on this subject by Croll, glass ionomers meet the objectives set forth here. For children, these materials have offered an alternative that has insidiously become a "standard of care" in a variety of clinical indications for children.

This paper will differentiate the clinical use of glass ionomers into a multitude of categories. The categories are based upon the clinical indication, and also on the specific material formulation used to fulfill the requirements of this identified clinical indication. It is sometimes useful to step away from an internal perspective and think of how dental patients and their caregivers view the choices dentists make,

including choices of restorative materials. Today, when the consumers of dental services are requesting to be better informed about the care and services dentists provide to their children, it behooves clinicians to continually reconsider their own perspectives on the clinical choices they make and on what evidence these choices are made.

In his illustrative book for parents, *The No Boring Science Take Care of Your Kid's Mouth Book*,¹ Croll defines glass ionomer materials as "a type of filling material that bonds to teeth..." This perspective provided to consumers of oral care for children perhaps summarizes the reason why glass ionomers are so useful in pediatric restorative dentistry. By virtue of the fact that glass ionomers are self-adhesive materials,² and are the only commonly used materials that chemically bond to tooth structure,^{3,4} the versatility of these materials in children has continually been expanded.

Clinical use of glass ionomer materials by category

This paper is structured to provide a position statement regarding each of the many clinical indications for glass ionomer materials in children. It is important to consider the matter in this categorical fashion, as different clinical situations offer different challenges, and the choice of material and the selected formulation of that material are critical in the success of the procedure.⁵ In addition, the handling properties of various versions of glass ionomer materials are important in the usefulness of glass ionomers in given clinical scenarios.

A topic not addressed in this paper is esthetics. Glass ionomer materials are provided in some formulations (most notably the resin-modified versions) as “esthetically desirable.” Although such enhancements in glass ionomer formulations have made it easier to use glass ionomers in an expanded set of circumstances, glass ionomer materials are not selected primarily because of their esthetic properties. Resin composite materials are far more esthetically desirable, and if esthetics is a primary objective of the procedure, then resin composites must be considered strongly if their use is otherwise possible.

Sealants

Studies have examined the use of glass ionomers as pit-and-fissure sealants.⁶⁻⁹ Prior to providing a position statement regarding the use of glass ionomers as sealants, it must be noted that resin-based sealants are the most effective materials for pit and fissure sealants.¹⁰⁻¹¹ Resin sealants, one of the most underutilized implementations into the world of preventive dentistry for children, work exceptionally well, and serve their function for many years when placed properly. Their limitation clinically is in the often-encountered difficulty relative to handling. To use a resin sealant, the tooth must be properly isolated and avoidance of contamination throughout the procedure must be guaranteed. Contamination can result in failure of the resin sealant.

Glass ionomers offer an alternative to resin sealants, and should be considered for use as a pit and fissure sealant only in certain situations. First, if resin sealants can be used, they should be used. Resins are the preferred materials for pit-and-fissure-sealants. If it is determined, due to clinical considerations, that resin sealants cannot be used, then glass ionomer should be considered. Particular clinical situations where the use of glass ionomers as sealant materials might be most useful include:¹²⁻¹⁵ (1) “precooperative” children with primary molars having deeply pitted or fissured surfaces, but are difficult to isolate, (2) permanent first or second molars that are not yet fully emerged into the mouth, or (3) situations where a “transitional” sealant can be considered prior to the placement of a (“permanent”) resin sealant.

Three other considerations need to be identified regarding the use of glass ionomer materials as pit-and-fissure sealants for children: (1) the physical properties of glass ionomer materials, (2) the formulation of glass ionomer selected for the procedure, and (3) the longevity of the glass ionomer sealant.

As noted in the literature review paper within this consensus conference report, glass ionomers are brittle materials. Pure (traditional) glass ionomers, when used as sealants, have been shown to exhibit a high frequency of fracture within the pits and fissures, although the glass ionomer material has tended to remain within the depths of the fissures as a result of their inherent ability to chemically bond to tooth structure, allowing a sealing effect to be in place in most cases. To compensate for the brittleness of traditional glass

ionomers, resin-modified glass ionomer materials have commonly been selected as alternatives.¹⁶⁻¹⁸ These materials offer greater strength and control (light initiation potential), but still lack the flowability and retentiveness of resin sealants when used on a properly isolated and conditioned tooth surface.

For the primary dentition, there are some scenarios where the longevity of glass ionomer as a sealant, particularly when formulated as a resin-modified glass ionomer, is adequate to allow survival until the eventual exfoliation of the tooth. Within the permanent dentition, the literature suggests that resin sealants should eventually be deployed (when indicated) within appropriately selected pits and fissures, with glass ionomer materials only being used as sealants in transitional situations.

Luting cement

Glass ionomer materials were first introduced as cavity-lining materials, and soon thereafter, these materials were used as luting agents. Subsequently, specifically formulated luting agents, now within even further subdivided formulations based on their intended clinical luting scenarios, have been introduced for the clinician.¹⁹ In addition, glass ionomers are available as luting agents formulated as traditional glass ionomer materials, and as resin-modified versions. These latter formulations have subsumed much of the clinicians’ attention in recent years, both because of their enhanced physical properties, and because of their ease of use in terms of handling properties.²⁰

However, when comparing the use of traditional vs resin-modified formulations of glass ionomer materials to be used as luting agents, the clinician must consider the related differences required in treatment of the tooth surface prior to placing the luting formulation onto the tooth surface. Traditional glass ionomer materials are self-adhesive, and only require removal of the smear layer via pretreatment with a solution of polyacrylic acid. Use of resin-reinforced glass ionomer as a luting agent generally requires some sort of self-etching adhesive procedure prior to the placement of the luting cement.

Crown cementation

Since their introduction in the 1970s and 1980s for this purpose, glass ionomers have become a material of choice for clinicians treating children, and in particular for the cementation of stainless steel crowns (SSCs).^{21,22} Whether these SSCs are precrimped or are crimped entirely by the clinician, they differ from laboratory custom-fabricated cast restorations or ceramic crowns in part because of the absence of a precision fit. Therefore, reliance on the luting cement as an effective interface to avert problems and to retain the crown itself is even more significant than with laboratory-fabricated crowns. Glass ionomers fulfill the many needs of this clinical challenge in the same manner they do in other formulations and in other clinical scenarios:²³ (1) they adhere chemically to the tooth structure, providing a sealing

of the dentinal surface, (2) they are hydrophilic and, therefore, provide an appropriate compatibility with the challenging environment of the mouth, and (3) they are easily cleaned from the surrounding area after cementation.²⁴

Retention of SSCs, accomplished primarily by virtue of the mechanically retentive design of the crown and its crimping adapted to the tooth preparation, is further enhanced by the excellent luting properties of both traditional and resin-modified versions of glass ionomer materials.²⁵ Resin cements, often selected as luting agents for laboratory-fabricated permanent tooth crowns, are generally not indicated for the cementation of SSCs. This is because of the greater clinical difficulty procedurally in using these materials (and the reduced time and ability to accommodate for this challenge in children).

Orthodontic band cementation

The use of glass ionomers in cementing orthodontic bands is not only appropriate, but also one of the strongest indications for the use of glass ionomer materials, both of the pure and resin-modified variety. This is an exceptional example of glass ionomers being perhaps “generally the material of choice” for most situations because of their inherent adhesive properties and because of their fluoride release.²⁶ Placement of orthodontic bands over a significant period of time puts those tooth surfaces at risk for decalcification and frank carious lesions because of the plaque biofilms trapped around them, creating a potential reservoir for acid producing organisms to exert their detrimental manifestations.

Fluoride release from glass ionomer materials, enhanced when these materials are exposed to the oral environment wherein the fluoride can go into solution and exert its protective effect by being taken up into surrounding enamel, is beneficial around orthodontic bands.²⁷ Clinicians have, therefore, selected glass ionomers as orthodontic band luting agents both for retention purposes and for the purpose of protecting the tooth from acid demineralization.^{28,29} Indeed, research has shown, and clinicians have indicated, that this appropriate use of a glass ionomers is a use of primary consideration.

It should be noted that, although glass ionomers chemically bond to the tooth structure in a luting scenario, their adhesion to the band itself is not as strong as their adhesion to the tooth surface.³⁰ Additional retention can be obtained by treating the underlying surface of the band to achieve additional mechanical retention. This can be accomplished with air abrasion most effectively.^{31,32}

Orthodontic bracket adhesive

Several laboratory studies have examined the bond strength of orthodontic brackets bonded with glass ionomer to enamel surfaces when used under forces commonly applied to those bracket/tooth interfaces during orthodontic tooth movement.³³⁻³⁵ Although the bond strength measured with resin-modified varieties has been sometimes deemed

“adequate” to allow orthodontic tooth movement to be successfully accomplished, these bond strengths are still statistically and dramatically lower than with resin-based bracket adhesives. In general, the position statement here can be cited as analogous to that concerning the use of glass ionomers as sealants.^{36,37} If resin-based systems can be used, they should be.

The exception to this comparison with the sealant situation is that there may be clinical scenarios where it is desirable to use an adhesive for orthodontic brackets with lower bond strengths to allow easier removal and less potential damage to the enamel surface upon bracket removal. Examples of such a scenario might include the use of resin-modified glass ionomer as an orthodontic bracket adhesive when the bracket is used to retain a splint applied after a traumatic injury to the anterior permanent dentition. Another example might be when brackets are placed for a short period of time within an isolated part of the mouth to achieve an isolated area of tooth movement. At least one manufacturer has marketed its resin-modified version of glass ionomer specifically as an orthodontic adhesive.³⁸⁻⁴⁰ As a future developmental direction, it may be possible to create further enhanced formulations of resin-modified glass ionomer, that could be routinely used as orthodontic bracket adhesives, to allow retention during the entire duration of treatment and facilitate removal while avoiding damage to enamel surfaces.⁴¹

Cavity liner

The first glass ionomer products introduced for clinical use were cavity liner formulations. This obvious choice of glass ionomers for this clinical scenario emanates from the fact that sealing, protection, and retention properties are inherent in glass ionomers.^{42,43} Highly flowable, low-viscosity versions of traditional glass ionomer as well as resin-modified glass ionomer have been used effectively as cavity liners for decades.⁴⁴ One could argue that it is difficult to differentiate between the use of glass ionomers as a cavity liner and their use as a “dentin replacement,” as a dentinal adhesive, or within a “sandwich technique” (discussed later).

Glass ionomers provide a simple and effective choice for the clinician to accomplish all of the objectives of cavity lining simultaneously. This advantage is particularly emphasized when children are treated, where the additional time required to use alternative techniques is not available.

Dentinal adhesive

As mentioned above, using glass ionomer as a dentinal adhesive is a natural extension of the idea that glass ionomers are ideal cavity liners. By using glass ionomers as an adhesive on dentin surfaces, above which resin composites are applied as a surface restorative material, one can accomplish several restorative objectives simultaneously.^{45,46} The cavity can be sealed, the retention of the surface resin composite can be achieved and resistance to further destruction can be avoided.

One issue that must be dealt with when considering using glass ionomer as an adhesive on dentin surfaces is concerning the enamel margin. Because of the less-than-ideal esthetics of glass ionomers (even the resin-modified variety) some have suggested using glass ionomers as an adhesive only for the dentin surfaces, while employing traditional resin adhesive techniques on the overlying enamel surfaces.

When doing this, because the clinician is then dealing only with enamel surfaces for adhesion (after covering the dentinal surfaces with glass ionomer), one must be careful not to use the resin adhesive in the same manner in which it was intended to be used on dentin, and use only the “adhesive” portion of the system (if it is a separated fourth-generation adhesive).

Regardless, this separated technique requires the additional use of a different material and may add unnecessary steps to an already challenging restorative procedure. This is the reason that many clinicians choose to use either a (resin modified) glass ionomer dentin adhesive or a resin adhesive for an individual procedure, but not both within the same procedure. At least one manufacturer markets a version of resin-modified glass ionomer intended to be used as an adhesive on dentin.

Because of the inherent adhesive properties of glass ionomers, and their protection of the underlying surfaces, many are reconsidering the use of resin-modified glass ionomers as adhesives in lieu of the sometimes-challenging placement of resin-based adhesives, wherein the precise wetness of the dentinal surfaces can dramatically affect the outcome of the procedure.^{47,48}

It is interesting to note that resin-modified glass ionomers, well-suited as dentinal adhesive for children, were introduced into the marketplace at approximately the same point in time when (effective) resin-based dentin adhesives were introduced in a significant way to the practitioner. Many clinicians realize the major effort expended by a variety of dental materials manufacturers to promulgate dentin adhesives in advertising, lectures, publications, and elsewhere. It is the observation of this author that perhaps the idea of using resin-modified glass ionomer materials as dentinal adhesives for children has been superimposed in a significant way because of the deluge of promotion relative to resin-based adhesives. Perhaps these resin-modified glass ionomer adhesives, when tested and developed to the extent that the resin-based adhesives have been developed, can provide even a more effective way to accomplish the objectives of a dentinal adhesive when performing restorative dentistry for children.

Sandwich technique/dentin “replacement”

It is perhaps difficult to distinguish or delineate between using glass ionomers as liners, dentinal adhesives, and the sandwich technique.⁴⁹ The sandwich technique gets its name from the fact that, in this particular usage, glass ionomers are “sandwiched” between the tooth surface below and the

(other) restorative material above, usually being resin composite.⁵⁰ There are a number of papers promoting the use of this technique, with more limited exposure to clinical testing of the technique with reported outcomes.⁵¹ The impressive 91% success rate of restorations in the primary dentition, reported by Mjör, indicated the 9% restoration failure group was represented by a 9% failure rate of amalgam restorations, 8% failure rate of traditional glass ionomer cement restorations and 7% failure rate of resin-modified glass ionomer cement restorations.

Although glass ionomers, both traditional and resin-modified, offer clear advantages, they do not possess the preferred physical properties of resin composites. Therefore, this sandwich technique allows the use of glass ionomers against the tooth surface, with the superficial aspects of the restoration—those exposed to the mouth and its biting forces—to have resin composite, a material that is both stronger and more esthetically desirable.⁵²

Glass ionomer is an ideal dentin replacement material. Its coefficient of thermal expansion, an important physical property, is very close to that of dentin. No other commonly used restorative material possesses this advantageous characteristic. In addition, the hydrophilicity of glass ionomers makes it well suited to bond and adapt to the dentin surfaces it covers and protects.⁵³

This sandwich technique is useful and realistic. Many clinicians choose it in specifically selected clinical scenarios—an example being in Class II restorations in the primary dentition where it is desirable to have the fluoride-releasing effects of glass ionomer at the contact point, with the physical properties of resin composite on the surface above.

Another example of a sandwich-type of technique using glass ionomers is within the so-called “tunnel preparation.”^{54,55} This technique requires occlusal preparation and angulated access to the contact point, wherein glass ionomer is placed against the adjacent tooth, as noted above. The occlusal opening is then restored with resin composite, as described above.

Restoration

The next logical extension of using glass ionomer materials beyond liner, dentin adhesive, or sandwich technique, would be to extend the glass ionomer from the preparation interface all the way to the surface—becoming the restoration itself.⁵⁶⁻⁵⁹ Glass ionomers, first as traditional glass ionomers and now predominantly as resin-modified materials (except for the ART technique, described later), have become a standard element in the armamentarium of restorative materials used for children. The physical properties of resin-modified materials that have been formulated for use as restorative materials, makes these materials useful not only because of their designed-in properties, but also because of their clinical handling.⁶⁰ Resin-modified glass ionomer restorative materials have the same command-cure properties of resin composites, in addition to possessing the separate glass ionomer reaction within. Furthermore, many of these

materials have a significant “dark cure,” or auto-cure resin feature, resulting in 3 distinct curing mechanisms of the material.⁶¹ This accomplishes a complete cure even in those areas of the preparation where the light has not reached for unintended reasons.

Using glass ionomers as restoratives has been around for some time. In the early 1980s, many studies looked at traditional glass ionomers as restoratives for children, either pure or reinforced with silver. These materials showed great promise in a variety of clinical trials performed at that time. Many of these (essentially the same) materials are still sold and used in large amounts today.⁶²

With the introduction of resin-modified glass ionomers several years later, even greater success in using glass ionomers as restoratives has been achieved. Clinicians treating children have cited the handling properties, as well as the fluoride release as primary reasons for selecting these materials in daily practice. As time has progressed since their introduction, these (resin-modified) glass ionomer materials have been continually improved, and each year results of new studies emerge with excellent long-term results.

Probably one of the most useful aspects of resin-modified glass ionomers as restorative materials is the fact that they are not as hydrophobic as resin composites, materials intentionally designed to be hydrophobic. Even though visible moisture may result in the clinical failure of resin-modified glass ionomers, it is the moisture that the clinician did not see (smaller amounts not visible during the procedure) that might be tolerated by the more hydrophilic resin-modified glass ionomer material; a material that itself contains water.

Class I restorations

When discussing resin composite restorations, the literature talks about “C-factor”—a way to describe the effect the number of bonded surfaces has on the restoration as a result of the polymerization shrinkage of resin composites. Because glass ionomers have significantly less shrinkage, their use is particularly advantageous in situations where the effects of polymerization shrinkage are potentially most manifested—in the Class I cavity preparation on the occlusal surface.⁶³ Class I restorations in the primary dentition are small preparations, and the use of either a pure or resin-modified glass ionomer material is extremely effective while allowing a “defect-specific” preparation.⁶⁴ In the permanent dentition, small, minimally invasive preparations can be restored with resin-modified glass ionomer, but if resin composite can be used alone or above, its greater physical properties and enhanced esthetics make it the preferable material.^{65,66}

Class II restorations

For the primary dentition, resin-modified glass ionomer is an ideal material for small- to medium-sized Class II restorations.^{67,68} Traditional glass ionomer, although tested and proven successful as a restorative material herein, is more

brittle, and the preparations must accommodate the brittleness and therefore be larger than the size of the defect.^{69,70}

Each year, new studies emerge with excellent results affirming the attributes of resin-modified glass ionomer for Class II indications in primary teeth.⁷¹⁻⁸² Many clinicians have abandoned the use of amalgam in children and have substituted resin-modified glass ionomer for those situations where they formerly would have used amalgam.

For permanent teeth, with the exception of sandwich restorations and small defect-specific restorations, resin composite is preferred in Class II scenarios because of its enhanced physical properties.

Class III restorations

For the primary dentition, glass ionomer is an ideal choice for small Class III restorations. For the same reasons as with Class II sandwich restorations using resin-modified glass ionomer, the proximal contact point is a location to take advantage of the unique fluoride-releasing properties of glass ionomer.⁸³

For permanent teeth, the less-than-ideal esthetics of resin-modified glass ionomer materials makes resin composites the material of choice, except for transitional circumstances.

Class V restorations

Class V-type restorations are common in the primary dentition in the form of early childhood caries lesion repair.⁸⁴ Because of the excellent self-adhesive properties of glass ionomers, both pure and resin-modified, many clinicians have used these materials on a temporal basis to treat the initial presentations of this “baby bottle tooth decay.”⁸⁵⁻⁸⁷

Another common use of glass ionomers of either formulation is to treat Class V type lesions associated with erosion, caries, or the combination of the 2 associated with inappropriate sugar or carbonated beverage consumption by teenagers. The presentation of this condition, and when considering the etiological factors, warrants the use of the (fluoride-releasing) glass ionomers to provide the potential for a therapeutic component of the restorative treatment.^{88,89}

For permanent teeth, Class V restorations can also be appropriately treated with either traditional or resin-modified glass ionomer materials. Much of the original clinical testing of glass ionomers looked at permanent teeth and Class V restorations. The longevity of these materials in these circumstances has been well tested and has proven quite effective. Again, one limiting factor here, as within all of the permanent tooth indications, is esthetics. Resin composites should be used when the ultimate benefit in esthetics is desired as a primary or secondary objective.

Buildup after pulp treatment

After pulpotomy in primary molars, or after pulpectomy or pulpotomy in primary anterior teeth, glass ionomers are useful in a type of sandwich procedure, whereby the surface is restored with resin composite. The lost dentin is

entirely replaced with resin-modified glass ionomer, and the surface above is restored with resin composite.^{90,91} Although there is not a good long-term clinical trial reporting on the outcomes of this procedure, there is a multitude of anecdotal information reported by practitioners for children to suggest effectiveness of these procedures to be sound.

Restorative dentistry for children is always looking for alternatives to restore primary teeth that have had a pulp procedure performed. Although a SSC is one option for these teeth, the use of a sandwich of glass ionomer and resin composite may allow a more esthetically desirable result.

ART technique

The so-called ART technique—atraumatic restorative treatment—has been introduced primarily using traditional glass ionomer materials. This technique employs the use of hand instruments to remove tooth structure affected by caries. The traditional glass ionomer is then hand mixed and placed into the cavity, with the glass ionomer reaction setting the material. The technique was introduced first in Thailand, and now into many other third world areas, to allow treatment of large numbers of children affected by caries, but without resources—sometimes even without electricity and water—to treat their teeth in alternative ways.⁹²

Specifically formulated glass ionomers have been developed for this ART technique. These are high powder-to-liquid ratio traditional glass ionomer materials, with enhanced physical properties. In addition, several highly refined and very sharp hand instruments have been developed to allow rapid excavation of damaged tooth structure, simultaneously “preparing the cavity.”^{93,94}

Results of many different long-term clinical trials have examined the effectiveness of these ART efforts.⁹⁵⁻¹⁰⁰ Most of these studies have reported on retention of the restoration as the primary outcome measure of the treatment. Some have looked at new caries beside the surface of restoration; none has developed a protocol comparing the ART technique to a control, such as a traditional in-chair technique.

In spite of this, many have touted the attributes of the ART technique because of the excellent outcomes measured in terms of restoration retention and the ability to treat large numbers of children in otherwise inaccessible and isolated areas—sometimes treated by practitioners who might not be able to perform standard procedures.¹⁰¹

The ART technique will likely be further tested and expanded, and some are looking into ways of medicinally treating the cavity prior to restoring the teeth with the glass ionomer material.

Summary

Glass ionomers have been a mainstay of restorative dentistry for children. Their many formulations, clinical uses, and unique advantages have made these materials an essential part of everyday practice for pediatric dentistry. It is likely that this will remain the case until such time that resin composite materials expand their own development and allow

much of what is offered to the practitioner via glass ionomers, including excellent handling, ease of use, self-adhesive properties and relative hydrophilicity.

The fluoride-releasing properties of glass ionomers will become even more important as caries diagnostic devices—now available for clinical use—become more sophisticated, and allow better sensitivity (interproximally) and specificity.^{102,103} Awareness about the abilities inherent therein will bring more attention to the value of fluoride-releasing materials when the localized effects of their use can be more precisely measured.

Recommendations

The dental literature supports the use of glass ionomer cement systems in the following situations:

1. Luting cement:
 - a. stainless steel crowns,
 - b. orthodontic band,
 - c. orthodontic brackets (limited).
2. Cavity base/liner.
3. Class I restorations in primary teeth.
4. Class II restorations in primary teeth.
5. Class III restorations in primary teeth.
6. Class III restorations in permanent teeth in high-risk patients or teeth that cannot be isolated.
7. Class V restorations in primary teeth.
8. Class V restorations in permanent teeth in high-risk patients or teeth that cannot be isolated.
9. Caries control:
 - a. high-risk patients,
 - b. restoration repair,
 - c. atraumatic restorative treatment.

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