EVALUATION OF TREATMENT TECHNIQUES FOR ADVANCED (GRADE II – IV) FURCATION DEFECTS. A LITERATURE REVIEW OF THE REGENERATIVE METHODS

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REZUMAT
Spre deosebire de furcațiile cu afectare precoce (gradul I), furcațiile de grad superior (II – IV) beneficiază de o varietate de opțiuni de tratament chirurgical, dar și de o rată relativ redusă de succes al tratamentului. Afectarea furcațiilor de gradul II de către boala parodontală poate fi tratată prin tehnici muco-gingivale (lambou repoziționat coronar) sau tehnici regenerative (grefe osoase sau substituenți osoși, membrane însotite sau nu de grefe osoase în regenerarea tisulară ghidată (GTR), agenti biologici de tipul proteinelor matricii smalțului sau factorilor de creștere osoasă, combinații de membrane cu grefe osoase și cu factori biologici, combinații de factori biologici cu grefe osoase etc.), cu rezultate variabile, dar care toate implică o reducere a adâncimilor de sondaj, un câștig de atașament clinic și o oarecare umplere a defectului osos. Furcațiile de gradul III și IV în schimb, nu beneficiază de terapie regenerativă, iar păstrarea molarului pe arcadă necesită alterari morfologice severe ale osului interradicular (tehnica tunelizării), ale coroanei molarului (hemisecție), sau pierderi ale unor întregi segmente corono-radiculare (amputare). În prezent, deși aceste tehnici sunt binecunoscute și au o vechime apreciabilă, există foarte puține studii controlate care să le evalueze succesul pe termen lung și beneficiul pentru pacient. Prezentul articolul încearcă să ofere o vedere de ansamblu asupra celor mai utilizate metode regenerative în tratamentul furcațiilor de gradul I și II.

Cuvinte cheie: defecte de furcație, terapia furcațiilor, regenerare tisulară ghidată, transplant osos, materiale de substituție osoasă

ABSTRACT
In contrast with early affected furcations (grade I), superior grade furcations (grade II-IV) benefit of a large variety of surgical treatments, however, the success rates of these procedures remains low. Grade II furcations can be solved by mucogingival techniques (coronally positioned flap) or by regenerative techniques (bone grafts in conjunction with bone grafts, biologic factors and combinations etc.), with various results in terms of pocket depth reduction, attachment level gain and defect fill. Grade III and grade IV furcations do not benefit of regenerative therapy, and maintaining of the molar requires often severe alterations of the interradicular bone (in the tunneling technique) or even of the crown (like hemisection and amputation). Although well known since long time ago, most of these techniques have not been systematically evaluated in long-term controlled trials. The present article tries to provide an overview of the currently used regenerative methods in the treatment of grade I and II furcation defects.

Key Words: Furcation defects, furcation therapy, guided tissue regeneration, bone transplantation, bone substitutes

INTRODUCTION
The therapy of furcation involvement depends primarily on the extent of the disease (as classified by Glickman), on the strategic importance of the affected tooth, and on the degree of patient cooperation and compliance. Therapies range from thorough debridement to regenerative procedures and, if the lesion progresses, to extraction. They all must begin with the initial periodontal treatment (systemic and cause-related phases, followed by re-evaluation) and must be sustained by the adequate hygiene of the patient, and by the close monitoring of the clinician.
THE CORONALLY POSITIONED FLAP (CPF)

The surgical technique for combination therapy of furcation defects has a common procedure, which is modified as necessary for specific situations. This common procedure employs a sulcular incision full-thickness envelope flap with maximum retention of gingival and papillary tissues and sufficient exposure of the defect for adequate visualization and access for debridement. The CPF was introduced by Norberg in 1926 as an aesthetic surgical procedure for root coverage with a coronally-displaced mucogingival flap. The technique described by Allen & Miller (1989) consisted of two oblique incisions, starting from the mesial and distal line angle of the affected tooth and directed apically in the alveolar mucosa; the flap was then elevated with a split-thickness approach to protect the underlying bone. Following root debridement, the flap was then coronally advanced and secured with interrupted sutures. Its objectives are: to cover the root and the furcation area, and to allow the recovery of furcation bone underneath the flap. In 1995, From & Tarnow had described the modified coronally positioned flap procedure for treatment of Class II and Class III molar furcation defects in conjunction with barrier membranes. This technique was designed to minimize barrier exposure during the healing phase and to cover and protect the newly formed granulation tissue following barrier removal.

The periosteum is viewed as having regenerative potential, due to its rich structure of osteoprogenitor cells. The regenerative potential is thought to result from a combination of the cellular activity of the periosteum and a barrier-type effect by the repositioned periosteum. When CPF are used to treat mandibular class II furcation defects, the position of the flap margin is placed coronally from the critical healing area (the furcation site) and secured. The prerequisite for using a CPF in the treatment of grade II furcation remains, however, the availability of a keratinized gingiva of sufficient width, which will allow its coronal displacement. An approximate mean of 50% to 65% (by volume) bone fill in class II mandibular furcation defects has been reported in studies that performed re-entry surgeries after CPF. In a clinical comparison of the new attachment obtained by GTR and CPF techniques in the management of human molar Class II furcation defects, Kerdevongbundit et al. (1999) had obtained similar results. After 12 months following surgical treatment, both GTR and CPF procedures showed gains in new clinical attachment levels. About 80% of the sites treated with the GTR technique showed complete clinical resolution of the furcation problem and only 50% of the cases treated with the CPF therapy reached the same treatment goal. They concluded that GTR appeared to be more effective in promoting regeneration than the CPF.

Some authors include root detoxification in such therapy, but this does not seem to improve the results obtained. Over the short term, CPF with or without root conditioning, whether accompanied or not by substitutions with freeze-dried, decalcified human bone (which ensure a support for the displaced flap), may provide good results, but improvements are lost within 4-5 years. The main drawbacks are the risk of lesion progression in the furcation hidden by the displaced flap. The therapeutic failure (the failed covering of the furcation) is followed by disease progression.

BONE REPLACEMENT GRAFTS (BRG)

BRGs are today still the most widely used treatment options for the correction of periodontal osseous defects. It has been proved that bone replacement grafts provide clinical improvements in periodontal osseous defects compared with surgical debridement (OFD) alone. BRG include autografts, allografts, alloplasts and xenografts. (Table 1)

Table 1. Available bone graft materials and their sources (after Bashutski & Wang).

<table>
<thead>
<tr>
<th>Source</th>
<th>Autogenous</th>
<th>Allograft</th>
<th>Alloplast</th>
<th>Xenograft</th>
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<td>Host</td>
<td>Different individuals</td>
<td>Synthetic</td>
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<td>Some osteoinductive?</td>
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grafts. Iliac grafts have had only limited use because of the difficulty in obtaining the graft material, morbidity, and the possibility of root resorption.7 However, bone autograft is considered to be the gold standard material for any regeneration procedure because of its osteogenetic, osteoinductive and osteoconductive properties.11

The combination barrier membranes and grafting materials for the treatment of furcation defects was evaluated by Sculean et al. (2008) in 3 preclinical canine model studies presenting histological evidences (Caffesse et al. 1993, Lekovic & Kenney 1993, Deliberador et al. 2006).12-15 The analysis indicated that no additional benefits of combination treatments were detected in models of Class II furcation defects. The results of these studies are presented in Table 2.

Allografts. A bone allograft refers to a graft between genetically dissimilar members of the same species. The grafts are often obtained from tissue banks that process the donor tissues. Depending on the manner in which these tissues are processed, allografts might be osteoconductive or osteoinductive.10 Iliac cancellous bone and marrow, freeze-dried bone allograft (FDBA), and decalcified FDBA (DFDBA) are the types of bone allografts widely available from commercial tissue banks.7 FDBA works primarily through osteoconduction. The graft does not activate bone growth but acts like a scaffold for natural bone to grow into. Eventually the graft is resorbed and replaced by new bone. When using FDBA to treat periodontal defects, trials indicate bone fill ranging from 1.3 to 2.6 mm. On the other hand, DFDBA is believed to induce bone formation due to the bone-inductive proteins called bone morphogenetic proteins (BMPs), exposed during the demineralization process. DFDBA is therefore thought to be simultaneously osteoinductive and osteoconductive. Superior gains in bone fill with DFDBA compared with OFD have consistently been reported. Human trials using DFDBA have demonstrated bone fill similar to that achieved with FDBA, ranging from 1.7 to 2.9 mm.7

Alloplastic materials are synthetic, inorganic, biocompatible, or bioactive bone graft substitutes. Alloplastic materials are believed to promote bone healing through osteoconduction.7 According to Moore et al. (2001), ideally alloplast bone substitutes should have the following properties: 1) biocompatibility, 2) minimal fibrotic reaction, 3) the ability to undergo remodeling and support new bone formation, 4) similar strength

<table>
<thead>
<tr>
<th>Study</th>
<th>Design</th>
<th>Parameters</th>
<th>Treatment groups</th>
<th>p value</th>
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<td>Control included</td>
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<td>57 (33-81)</td>
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<td>62 (53-71)</td>
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comparable to cortical/cancellous bone, and 5) similar modulus of elasticity comparable to bone to prevent fatigue fracture under cyclic loading.\textsuperscript{16} A variety of materials have been used to treat periodontal defects as hydroxyapatite, beta-tricalcium phosphate, non-ceramic, polymer, or bioactive glass. Alloplasts may be divided into ceramic and non-ceramic categories. Ceramic materials may be further divided into absorbable and nonabsorbable materials. Absorbable ceramics include tricalcium phosphate and absorbable hydroxyapatite. Non-resorbable ceramics include dense hydroxyapatite and porous hydroxyapatite. Non-ceramic absorbable materials include plaster of Paris. Non-ceramic, nonabsorbable materials include bioactive glass and a calcium-coated polymer consisting of polymethylmethacrylate (PMMA) and hydroxyethylmethacrylate (HEMA).\textsuperscript{17}

Hydroxyapatite grafts can achieve attachment gains of around \(-1\) to \(-1.5\) mm, and polymer grafts can average 2 mm of bone fill. However, tissue/bone regeneration is highly unpredictable in these cases.\textsuperscript{10,18,19} When compared to OFD, the most dramatic changes are reported in a clinical trial by Froum et al. (1976), comparing bioactive glass to debridement alone.\textsuperscript{20} The debridement arm in this study had greater mean soft tissue changes than in other reports.\textsuperscript{21-25} Initial PD and defect depths were similar to the other reports in the group. Overall, PD reduction for the Class II defects ranged from 1.9 mm to 2.31 mm for BRG when compared to their controls (OFD alone) which attained a PD reduction of 0 mm to 1.8 mm.\textsuperscript{21,23,24} For Class III defects, grafts produced a change of 0.7 mm to 2.43 mm, as opposed to the controls, that attained a PD change of -1.0 to 2.6 mm.\textsuperscript{22,24,25} Clinical attachments level changes were similar for mandibular Class II and III defects. The graft treatment groups ranged from a mean change of 1.6 mm to 1.9 mm for the Class II defects and 2.2 mm to 2.6 mm for the Class III defects. Their debridement control groups attained mean clinical attachment level reductions of -0.04 mm to 1.5 mm and 0.43 mm to 1.5 mm, respectively.\textsuperscript{26}

An oily calcium hydroxide suspension has been lately used to treat periodontal infrabony defects.\textsuperscript{27,28} So far, the oily calcium hydroxide suspension has never been tested on furcation defects, neither animal nor human.

Controlled clinical comparison studies have demonstrated greater pocket depth reduction, greater gain in CAL and greater defect fill with both the absorbable and nonabsorbable allografts when compared to OFD.\textsuperscript{17,29} These materials have demonstrated comparable clinical results to autogenous and allogenic grafts.\textsuperscript{9} Moreover, 5-year and 4-year evaluation of dense hydroxyapatite in intraossseous defects, and a 6-year evaluation of the coated copolymer in furcation defects showed continued clinical stability over time.\textsuperscript{30-32} While many of these materials serve as scaffolds for new bone, to date, in histological studies, allografts have failed to demonstrate new cementum and a functionally oriented ligament.\textsuperscript{17}

The mean soft and hard changes in clinical outcome measures (PD = probing depth, CAL = clinical attachment level, REC = gingival recession, CR = crestal resorption, VDF = vertical defect fill, HDF = horizontal defect fill, FC = furcation closure) in the most important studies examining bone replacement grafts in the treatment of Class II and III furcation defects can be found in the excellent recent systematic review of Reynolds et al. (2003).\textsuperscript{26}

Xenografts. A xenograft (heterograft) refers to tissue taken from one species and placed into another species. For introral bone replacement grafts, the most common animal sources are bovine and porcine. Because antigenicity is a concern with this type of graft, the tissues are processed to remove all organic constituents, leaving only an inorganic matrix. Thus, xenografts are osteoconductive by nature.\textsuperscript{10}

A bovine derived xenogenic bone graft (BDX) has been extensively used with positive clinical results over the last decade in the treatment of periodontal infrabony and furcation defects, alone or in combination with membranes or enamel matrix derivatives.\textsuperscript{30,35-35} In a comparative evaluation of BDX (Bio-Oss®) with and without a bioresorbable collagen barrier (BG) in the treatment of mandibular Class II furcation defects, Reddy et al. (2006) observed that both treatment procedures resulted in statistically significant reduction in VPD and HPD, gain in CAL, and reduction in VDF and HDF.\textsuperscript{36} They concluded that the findings suggest superior clinical results with Bio-Oss/BG treatment when compared to Bio-Oss treatment in mandibular class II furcation defects. On the other hand, Taheri et al. (2009) had concluded that is no superiority of the combined use of Bio-Gide and Bio-Oss to the use of Bio-Oss alone in the treatment of mandibular Class II furcation defects, although both therapies resulted in significant gains in attachment level and bone fill.\textsuperscript{37}

Other studies have compared the BDX to DFDBA in the treatment of human intrabony defects and Grade II furcation defects, with no statistical difference between the 2 materials in all measurements.\textsuperscript{38-40} Thus, according to Kothiwale et
GUIDED TISSUE REGENERATION (GTR)

The principle of GTR was promulgated in 1982 by Nyman et al. for treatment of osseous defects in human periodontal defects. The concept of GTR is based on the exclusion of gingival connective tissue cells and prevention of epithelial down growth into the wound, thereby allowing cells with periodontal regenerative potential (PDL cells and bone cells) to enter the periodontal wound first. Barrier techniques, using materials such as expanded polytetrafluoroethylene, polyglactin, polylactic acid, calcium sulfate and collagen are widely employed nowadays, in the hope of excluding epithelium and the gingival corium (the conjunctive submucous layer) from reaching the root, in the belief that they interfere with periodontal regeneration.

Absorbable and non-absorbable membranes have been advocated and no differences have been detected among barrier types. However, non-resorbable membranes without grafting material were found to be superior to collagen without graft material. Because non-resorbable membranes require a second surgical procedure for removal, biodegradable membranes (either of collagen or polylactic acid) are now commonly used.

In periodontal intrabony defects, the use of membranes has resulted in a weighted mean difference of CAL gains of 1.1 mm when compared with access flap, while for GTR + bone substitutes, the weighted mean difference when compared with access flap was 1.25 mm. Overall, GTR was more effective than OFD in improving attachment levels, while OFD should remain the control comparison in these studies.

GTR has been shown to be useful in the treatment of grade II furcation lesions. The possibility of failure due to the exposure of the surgical membrane or infection must also be taken into account. Some authors suggest that the use of bone substitution materials (either as having osteoconductive properties or just as providers of support for the membranes to prevent their collapse over the furcation defect) improves the outcome of this type of treatment, while others report no improvement over the use of surgical membranes alone.

Novaes and Novaes (1992) reported 8 different situations of class II furcations in which GTR is not indicated: a) lack of access for adequate debridement of the furcation, b) endodontic or prosthetic perforations in the furcation areas of the roots, c) crown lengthening procedures that invade the furcations, d) root proximities untreatable by the restorative alveolar interface (RAI) technique, e) extensive gingival recessions, f) deep caries involving the roots, g) untreatable endo-perio lesions, and h) longitudinal root fractures. In these cases, hemisection is recommended.

Clinical closure (complete resolution) of grade II and grade III furcation defects is not predictable, according to the literature. For instance, one study demonstrated 14 of 21 membrane-treated sites obtained complete clinical closure of grade II buccal furcation defects. However, other research showed only 1 of 11 furcations clinically closed in six months.

However, GTR in combination with various types of bone grafts remains one of the most successful surgical regenerative therapies for grade II furcation defects.

To achieve success of GTR in Class III mandibular furcations, researchers and clinicians have included all or just some of the following to ensure clinical success: citric acid root conditioning, placement of freeze-dried bone allografts, barrier membranes, or coronal flap positioning. GTR should only be attempted with lesions that are under control, isolated, and when the patients can easily maintain hygiene. The outcome, however, is very uncertain. Pontoriero et al. (1997) stated that vertical bone loss of more than 3 mm will limit the success of any attempt at GTR of mandibular molars with Class III furcations. Thus, any Class III mandibular furcation with a vertical subclassification of B or C would not be indicated for a GTR procedure.

The greatest success in treatment of Class III furcations was reported in a 6-month comparison study of 21 pairs of matched Class III mandibular furcation defects treated with either ePTFE membranes or OFD. The authors reported 8 defects healing with complete closure, 10 showing partial closure and 3 still open. None of the 21 OFD-treated defects showed complete closure.

GTR procedures compared with OFD controls show more favorable gains in vertical probing attachment level, reductions in vertical probing depth, and improvement in horizontal open probing attachment measurements. The most favorable
results are in class II mandibular furcations.\textsuperscript{43,36,57} Less favorable results are found in mandibular and maxillary class III defects and maxillary class II defects, as stated in the literature review of Wang & Cooke from 2005.\textsuperscript{7,58-61} Garrett et al. (1994) succinctly summarized the GTR approach to treating the mandibular Class III: “Present available methods do not provide satisfactory results for the majority of cases.”\textsuperscript{31,42}

The best results are found using a combination of GTR and bone replacement grafts (91\% overall improvement). Least favorable results are found with open-flap debridement (15\% overall improvement). GTR procedures for furcation treatment should be limited to mandibular and some maxillary buccal class II furcation defects.\textsuperscript{7}

**GROWTH FACTORS**

The commercial availability of growth factors, bone morphogenetic proteins (BMPs) and amelogenetic protein matrix has provided a new focus for the regenerative treatment of furcation defects. These products can be used alone or in combination. Unfortunately, the cost/benefit ratio for these techniques is poor, and the cost a patient has to pay for every millimeter regenerated is very high.\textsuperscript{2}

More recently, the use of the above-mentioned substances has shown promising results in the treatment of advanced furcation defects. Two animal studies have reported significant regeneration in grade III mandibular furcation defects in beagle dogs: Park et al. (1995) reported significant new bone and periodontal ligament formation in grade III furcation lesions at 8 and 11 weeks using PDGF-BB.\textsuperscript{62} At 11 weeks, the newly formed bone filled 87\% of the defects compared to 60\% bone fill with GTR alone.

Giannobile et al. (1998), reported that human osteogenic protein-1 (OP-1, 7.5mg/g) in a collagen vehicle led to significantly greater new bone, cementum, and periodontal ligament formation in surgically created grade III furcation defects compared to surgical debridement with the collagen vehicle or surgical debridement alone.\textsuperscript{63} In the first human study of growth factors, Howell et al. (1997), reported that furcation lesions responded most favorably to the application of both platelet derived growth factor and insulin-like growth factor-I.\textsuperscript{64} These and other studies have established the promising regenerative potential of growth factors and BMPs in furcation areas, but additional studies are needed to fully establish the value of these biologic modifiers in the treatment of human furcal defects.\textsuperscript{35}

**THE ENAMEL MATRIX DERIVATIVES AND ASSOCIATED COMBINED TECHNIQUES IN TREATMENT OF FURCATION DEFECTS**

Results from basic research have pointed to the important role of the enamel matrix protein derivative (EMD) in the periodontal wound healing. A recent systematic review has summarized the existing data as follows: histological results from animal and human studies have shown that treatment with EMD promotes periodontal regeneration and clinical studies have indicated that treatment with EMD positively influences periodontal wound healing in humans.\textsuperscript{30}

Surgical periodontal treatment of deep intrabony defects with EMD promotes periodontal regeneration and may lead to significantly higher improvements of the clinical parameters than open flap debridement alone. The results obtained following treatment with EMD are comparable to those following treatment with GTR and can be maintained over a longer period. Treatment of intrabony defects with a combination of EMD + GTR does not seem to additionally improve the results compared to treatment with EMD alone or GTR alone.

The combination of EMD and some types of bone grafts/bone substitutes may result in certain improvements in the soft and hard tissue parameters compared to treatment with EMD alone. Treatment of recession-type defects with coronally repositioned flaps and EMD may promote formation of cementum, periodontal ligament and bone, and may significantly increase the width of the keratinized tissue, providing better long-term results than coronally repositioned flaps alone. Finally, application of EMD may enhance periodontal regeneration in mandibular Class II furcations, with clinical results comparable to those obtained following GTR. The surgical procedure is similar to the application of EMD in regular vertical periodontal defects. (Figure 1a-h)

Other studies concluded that EMD therapy promoted a reduction in the number of proximal furcations presenting a diagnosis of class II after 24 months of treatment compared with OFD therapy.\textsuperscript{66} However, the use of EMD in proximal furcations did not promote a superior reduction in PD or a gain in clinical and osseous attachment levels, but resulted in a higher rate of class-II to class-I furcation conversion.\textsuperscript{67}

Two multicenter, randomized trial compared enamel matrix derivative (EMD) with barrier membranes for the treatment of Class II mandibular furcations with regard to primary outcomes (open
horizontal furcation depth) and secondary outcomes (changes of the hard tissue boundaries describing the anatomical situation of the furcation defect and changes in the following clinical parameters between baseline and 14 months: plaque, level of gingival margin, probing depth, bleeding on probing, attachment level, and bone sounding at five sites/tooth at the buccal side). The influence of furcation morphology on the effectiveness of either treatment was also evaluated. There was a significantly greater reduction in horizontal furcation depth and a comparatively lower incidence of postoperative pain/swelling following enamel matrix derivative compared to membrane therapy. With regard to secondary outcome parameters, enamel matrix derivative treatment led to a similar regenerative result as the membrane procedure.

**CONCLUSIONS**

The goals of therapy in furcation areas are the same as the goals in all periodontal therapies: arresting the disease process (inflammation & infection), restoring the lost tissues and ultimately, maintaining the teeth in

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**Figure 1.** Buccal class II furcation defect on molar 4.6. a) Radiographic image of molar 4.6. The furcation lesion is slightly visible. Note the heavy calcifications in the pulp chamber, which may have indirectly contributed to the furcation involvement. b) Probing of the vertical depth of the furcation. c) Probing of the horizontal depth of the furcation. d) The Grade II furcation exposed. e) Following careful debridement, application of the root surface conditioner EDTA. f) Application of EMD (Emdogain®, Straumann AG, Switzerland). g) The operated area sutured. h) The open pulp chamber. Massive calcification (pulpitis) is visible.
health and function with appropriate esthetics. The decision for a specific treatment for a periodontitis-
affected furcation certainly depends on several factors. Tooth type and degree of furcation involvement may be regarded by as the most important factors influencing the decision, but more factors should be taken into account as well:12
- Local factors – tooth anatomy, tooth mobility, crown: root ratio, severity of attachment loss, inter-
arch and intra-arch occlusal relationship, strategic dental value for retention or removal;
- Patient factors – systemic health/host resistance, emotional value of the tooth to the patient, involvement and commitment in time and money;
- Clinician factors – diagnostic and treatment planning skills, awareness of therapeutic options and clinical skills in performing the procedures.

While grade I early furcation involvements are generally treated well with effective plaque control and scaling and root planning, early grade II and III furcations require surgical management. Surgery permits access for root debridement, odontoplasty, osseous recontouring and periodontal regeneration. Advanced defects require endodontic therapy and resection of the root or part of the tooth with advanced bone loss. However, grade II and III furcation involvement have shown good prognosis if treated appropriately.10

REFERENCES


