



## STRATEGIC CONSIDERATIONS IN TREATMENT PLANNING: DECIDING WHEN TO TREAT, EXTRACT, OR REPLACE A QUESTIONABLE TOOTH

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Prosthodontists face the difficult task of judging the influence and significance of multiple risk factors of periodontal, endodontic, or prosthetic origin that can affect the prognosis of an abutment tooth. The purpose of this review is to summarize the critical factors involved in deciding whether a questionable tooth should be treated and maintained, or extracted and possibly replaced by dental implants. A MEDLINE (PubMed) search of the English, peer-reviewed literature published from 1966 to August 2009 was conducted using different keyword combinations including *treatment planning*, in addition to *decision making*, *periodontics*, *endodontics*, *dental implants*, or *prosthodontics*. Further, bibliographies of all relevant papers and previous review articles were hand searched. Tooth maintenance and the acceptance of risks are suitable when: the tooth is not extensively diseased; the tooth has a high strategic value, particularly in patients with implant contraindications; the tooth is located in an intact arch; and the preservation of gingival structures is paramount. When complete-mouth restorations are planned, the strategic use of dental implants and smaller units (short-span fixed dental prostheses), either tooth- or implant-supported, as well as natural tooth abutments with good prognoses for long-span FDPs, is recommended to minimize the risk of failure of the entire restoration. (J Prosthet Dent 2010;104:80-91)

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Restorative therapies using crowns and fixed dental prostheses (FDPs) or removable prostheses are required to replace missing teeth or tooth substance.<sup>1</sup> The recent success of dental implants has resulted in substantive changes in treatment strategies for removable dental prostheses (RDPs) when extension bases can be avoided, and for FDPs when there are caries-free or well restored adjacent teeth, which otherwise would have been prepared for abutments with a substantial loss of tooth structure. Additionally, implants are more frequently used to replace teeth with a questionable prognosis.<sup>2-5</sup> Some authors even regard implants as “the better tooth” or “the more reliable abutment,” and propose the extrac-

tion of salvageable teeth.<sup>6-8</sup>

The diagnosis of a tooth based on periodontal, endodontic, and restorative parameters is always related to a certain prognosis. The tooth is classified as (1) good or questionable, but treatable, or (2) hopeless, with extraction required. Particularly for questionable teeth, several aspects should be considered when clinicians are faced with the decision to treat or extract and replace a tooth with a dental implant. In this decision-making process, one of the most crucial factors is the complexity of the treatment plan. A single crown in an intact arch is the simplest option, whereas a complete-mouth restoration that requires incorporation of the respec-

tive tooth is the most complex situation.<sup>9</sup> Although clinicians are continually confronted with the decision to either treat or extract questionable teeth in daily practice, a controlled clinical study that considers all influencing factors would, for ethical and practical reasons, not be feasible to design and conduct. For complex scenarios, evidence-based dentistry relies more on the clinical expertise of clinicians (internal evidence) and patients’ desires than on external evidence from the literature.<sup>10</sup> The purpose of this review is to summarize the key prognostic factors, from a periodontal, endodontic, implant, and prosthodontic point of view, that are relevant for deciding whether to

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treat and maintain a questionable tooth or to extract it and possibly replace it with a dental implant.

## REVIEW OF THE LITERATURE

The authors, who are specialists in periodontics, endodontics, and restorative and prosthetic dentistry, developed and explained their personal strategies for deciding when to treat, extract, or replace a questionable tooth, based on the best available external evidence and their clinical expertise. A MEDLINE (PubMed) search of the literature published from 1966 to August 2009 was conducted using different keyword combinations including the terms *treatment planning*, and *decision making*, *periodontics* (31), *endodontics* (49), *dental implants* (59), or *prosthodontics* (139). After eliminating double citations, 178 abstracts of full-text articles were evaluated, and 22 were included. Any relevant work published in the English lan-

guage in peer-reviewed journals and presenting pertinent information related to the purpose of this overview was considered for inclusion. Articles were excluded if no English abstract was available, if only single clinical reports or conference reports were included, or if the topic was not related to the subject. In addition, bibliographies of all relevant papers and previous review articles were hand searched. For those aspects lacking external evidence, a consensus view was presented based on the authors' clinical expertise.

### Periodontal aspects

In periodontics, the classification of teeth as having a good, questionable, or hopeless prognosis is based on the amount of attachment loss and residual probing pocket depth or furcation involvement.<sup>11,12</sup> This prognosis assessment is generally performed at different stages of peri-

odontal therapy: first at baseline, then during reevaluation following the initial nonsurgical therapy and after the active phase of periodontal therapy, and then before the restorative treatment planning, including implant placement. The resulting prognosis implies a consecutive recommendation for the recall interval and additional treatment modalities, if required. Teeth with a good prognosis are maintained, those with a questionable prognosis are retreated, and hopeless teeth are extracted (Table I). While no bleeding on probing (BoP), no further clinical loss of probing attachment level (PAL), and a residual probing pocket depth (PPD) of  $\leq 5$  mm are good predictors for a stable situation, a PPD  $\geq 6$  mm and additional loss of PAL are predictive of further disease activity.<sup>13</sup>

In a retrospective study, tooth loss that occurred during maintenance (after completion of active therapy) was analyzed in a group of

**TABLE I.** Prognostic assessment of potential abutment tooth or dental implant

| Prognosis Factors | Good                                                                                                                                                                  | Questionable                                                                                                       | Hopeless                                                                                                          |
|-------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------|
| Periodontal       | PPD $\leq 3$ mm, BoP <sup>-</sup> , PAL loss $\leq 25\%$ , FI degree $\leq 1$                                                                                         | Residual PPD $\geq 6$ mm and BoP <sup>+</sup> , PAL loss of approximately 50%, FI degree II or III, root proximity | Insufficient residual attachment                                                                                  |
| Endodontics       | No clinical signs and absence of or decreasing radiolucency                                                                                                           | No clinical signs and persisting radiolucency                                                                      | Symptomatic situation and radiolucency, no further treatment feasible                                             |
| Implants          | Absence of BoP, suppuration, bone loss                                                                                                                                | BoP with/without bone loss                                                                                         | Mobility                                                                                                          |
| Prosthetic        | Sufficient residual tooth substance, adequate retention and resistance forms (ideally, 4-mm wallheight with 15- to 20-degree convergence angle, 1.5- to 2-mm ferrule) | Reduced retention/resistance form ( $< 3$ -mm wall height and/or $> 25$ -degree convergence angle)                 | Insufficient residual tooth substance ( $< 1.5$ -mm circular ferrule), no crown lengthening or extrusion feasible |

PPD: probing pocket depth; BoP: bleeding on probing; PAL: probing attachment level; FI: furcation involvement (degree 0 to 3)

patients, primarily with generalized advanced periodontitis, and predisposing factors for tooth loss were residual PPD  $\geq 6$  mm, BoP<sup>+</sup>, and full mouth bleeding scores  $\geq 30\%$  after active treatment.<sup>14</sup> Overall, 7% of all teeth were lost during maintenance, and two thirds of the teeth with residual PPD  $\geq 7$  mm were lost. Further, tooth loss occurred particularly after  $\geq 10$  years of supportive periodontal care, and was restricted to 55% of the patients, indicating a susceptibility of this particular group of patients. While teeth with residual PPD  $\geq 5$  mm were extracted primarily because of periodontitis progression, it was assumed that the reasons for tooth loss with residual PPD  $< 5$  mm differed, and included root fracture, caries, or sequelae of endodontic treatment.<sup>14</sup>

In other studies, predisposing factors for tooth loss were related to the initial examination (at baseline) with PPD  $> 7$  mm, tooth mobility grade 3 (grading 0-3), attachment loss of  $\geq 75\%$ , multirooted teeth, degree II and III furcation involvement (FI), nonvital pulp, and caries.<sup>15,16</sup> Further patient-related factors have also been suggested, such as poor personal oral hygiene, inadequate compliance with the supportive care program, smoking, diabetes, and a family history of disease manifestation.<sup>15-17</sup> However, for periodontally involved teeth, the initial assessment does not adequately predict tooth survival, and a reevaluation 6-8 weeks following completion of active therapy (at the earliest) is required to adequately predict tooth prognosis, particularly when the questionable tooth is intended for incorporation as an abutment in an FDP.<sup>18</sup>

In patients with severe disease progression, the number of extractions performed during the initial phase inevitably affects the occurrence of tooth loss during maintenance. Matuliene et al<sup>14</sup> reported that 14.4% of the teeth initially present in patients with moderate to severe periodontitis were extracted. Approximately half of the extractions

were performed during the phase of active therapy, and the other 49% occurred during the maintenance period of, on average, 11 years.<sup>14</sup> When more questionable teeth are extracted initially, the number of teeth lost due to periodontitis progression during maintenance is decreased, and vice versa.<sup>14,16,19,20</sup> It is easier to predict the prognosis for single-rooted teeth, as they respond better to periodontal treatment and are less likely to be lost due to periodontal factors than multirooted teeth.<sup>12</sup> Among periodontally compromised teeth, maxillary molars are the teeth most likely to be lost.<sup>21,22</sup> This reduced efficacy of conventional periodontal therapy in molars is primarily related to complicating anatomical factors, such as furcation entrance diameters  $< 1$  mm or root concavities and bifurcation ridges inhibiting adequate personal plaque control and sufficient access to professional cleaning.<sup>23</sup>

While degree I furcation involvement (FI) can be successfully treated by nonsurgical mechanical debridement, surgical treatment may be indicated for degree II and III FIs to eliminate the plaque-retentive morphology and to provide access for plaque removal by the patient and for professional maintenance.<sup>24</sup> Surgical interventions include the apically repositioned flap with or without tunneling, and resective procedures, including hemisection and the amputation of 1 or 2 roots.<sup>25</sup> The most frequent complications following surgical treatment of furcation-involved molars, potentially resulting in tooth loss, are caries in the furcation after tunneling procedures, vertical root fractures, and endodontic failures after resective procedures.<sup>25</sup> The prognosis of tunneled molars was found to be improved when regular periodontal maintenance and continuous exposure to fluoride were applied.<sup>26</sup> Among resected molars, those resected because of nonperiodontal problems (tooth fracture, dental caries, and endodontic problems) had lower survival rates than mo-

lars resected because of periodontal problems.<sup>27</sup> Having more than 50% of bone support for the remaining roots was found to be a good predictor for tooth survival.<sup>27</sup> Fugazzotto<sup>28</sup> investigated resected molars and single tooth implants over at least 5 years in 2 different groups of patients, and found similar success rates of 96% after 11-13 years. Among resected molars, retained mesial roots in the mandible were most likely to be extracted (75% success), particularly when located in a terminal position without splinting to adjacent teeth. Implant failures dominated in the second molar position of the mandible with an 84% success rate, compared with 98-99% in the maxilla and first molar position in the mandible. In the second molar position of the mandible, 4% of the implants were found to be mobile during second-stage surgery (abutment connection), and another 7.5% were lost during the first to third year of functional loading; these failures were associated with nonsplinted implant restorations and patients with parafunctional habits.<sup>28</sup>

Several authors have addressed the issue of insufficient bone volume, particularly in the posterior region in situations involving questionable molars with advanced furcation involvement.<sup>29-33</sup> Root resection may be the treatment of choice if the tooth in question has a high strategic value, if its proximity to anatomical landmarks (such as maxillary sinus, mandibular canal) limits the amount of bone available for dental implants, and/or if the patient's medical situation prohibits multiple reconstructive surgical procedures.<sup>32</sup> (This issue is further addressed in the "Implant aspects" section of this article.) However, the clinician has to evaluate and consider the amount of bone removal required to properly resect a root, which depends on the length of the root trunk and the ability to eliminate plaque retentive areas.<sup>33</sup> When root resection must be accompanied by ostectomy to form a positive alveolar architecture, the removal of

surrounding bone may preclude preservation of adequate bone height for an implant should the molar tooth be later lost (again, see Implant aspects section).<sup>31,33</sup>

### Endodontic aspects

When determining prognoses for endodontically treated teeth, the decisive factors for a good prognosis are the absence of clinical signs and symptoms and no periapical radiolucency. These criteria entail that any endodontic treatment in a nonvital tooth with apical radiolucency starts with a 0% success rate, and several months or even years are required for complete healing of the periapical bony lesion. Hence, a reduction in size of the periapical radiolucency over 4 to 5 years is considered a sign of the healing process.<sup>34,35</sup> Instead of just reporting “success” or “failure” for the outcome of root canal treatment (RCT), it would be better to evaluate it as “success/healed or healing,” which is equivalent to a good prognosis; “diseased/survival,” comparable with a questionable prognosis; and “failure,” corresponding to a poor prognosis (Table I).<sup>34,36</sup> The potential for late healing, particularly following endodontic retreatment, has been demonstrated in a long-term study by Fristad et al.<sup>37</sup> The authors reported an 86% success rate of periapical healing from radiographs after 10 to 17 years postoperatively, while the same sample had a 96% radiographic success rate 10 years later.<sup>37,38</sup>

The observation period and the inclusion criteria for teeth initially presenting with or without periapical radiolucency clearly have a direct impact on the success rate. Ng et al<sup>39</sup> investigated the outcome of primary RCT in a meta-analysis, and reported a 75% success rate when strict criteria (absence of periapical radiolucency) were applied, and an 85% success rate based on loose criteria (reduction in size of radiolucency). The preoperative absence of periapical radiolucency, RCT with no voids, RCT extend-

ing to 2 mm within the radiographic apex, and a satisfactory coronal restoration were found to improve the outcome of primary root canal treatment significantly.<sup>39,40</sup> Although there is no clear evidence that single-rooted teeth have a better prognosis than multirooted teeth,<sup>35,36,41</sup> clinical reports indicate a lower chance of survival for molars, particularly mandibular molars.<sup>9,34,42,43</sup>

Recent reviews have examined the treatment outcomes and factors influencing the decision to preserve endodontically treated teeth or replace them with implants.<sup>44,45</sup> In the studies included, no differences in treatment outcomes were determined, which means that replacement of compromised teeth that can be saved by endodontic therapy is rarely justifiable.<sup>44,45</sup> Another systematic review compared the outcome of RCT and restorations with implant-supported single crowns, FDPs, and extraction without replacement.<sup>46</sup> According to the review, comparative studies are lacking and the applied success criteria vary tremendously. Combined success rates after 6+ years were 84% for endodontically treated teeth, 95% for implant restorations, and 81% for FDPs.<sup>46</sup>

The direct outcomes of initial non-surgical root canal treatment and single tooth implants were compared in a retrospective cross-sectional analysis.<sup>47</sup> Similar failure rates (6%) were reported for both treatment groups, but significantly more implants required some type of posttreatment intervention and were classified as “surviving” instead of “successful”.<sup>47</sup> Clinical complications were observed in 18% of the restored implants and 4% of the endodontically treated teeth. The complications in surviving teeth were primarily related to endodontic retreatment requirements or persistent apical periodontitis (AP), as assessed from radiographs, while in implants, several technical problems occurred or surgical interventions were required to treat periimplantitis (see also Implant aspects).<sup>47</sup>

In a recent review, it was noted that a potential bias exists when comparing data from endodontic and implant studies, due to the different professional backgrounds of the therapists.<sup>9</sup> While studies documenting the success or survival of endodontically treated teeth are primarily based on data from undergraduates and general dentists, most implant studies report data from university settings and/or specialist clinics.

In the endodontic literature, most failures of endodontically treated teeth are attributed to nonendodontic causes, while pure endodontic reasons for failure are rare. Endodontic causes include residual intracanal infection in nonaccessible regions of the canal system or periapical infections due to persisting microbiota, instrumentation failures, vertical root fractures, root resorption, presence of true cysts, or foreign body reactions, particularly to overfilled root canals (Figs. 1 and 2).<sup>48-50</sup> Nonendodontic reasons for RCT failure may be related to preexisting factors such as severe periodontal disease, postendodontic treatment factors such as recurrent caries, prosthetic failures such as improper reconstruction with coronal leakage and subsequent reinfection, crown fracture, or root fracture at the level of the post.<sup>51-53</sup>

In a study evaluating the reasons for failure of endodontically treated teeth, prosthetic reasons dominated and explained almost 60% of the failures; 32% failed for periodontal reasons, while pure endodontic failures were rare and accounted for less than 10%.<sup>54</sup> Prosthetic and periodontal failures mostly occurred after an average of 5 to 5.5 years, whereas endodontic failures were recognized within a 2-year period after RCT had been completed.<sup>54</sup> In a study comparing the outcomes of endodontically treated teeth with or without crown placement following obturation, teeth not restored with crowns were extracted 6.0 times more frequently than teeth crowned after RCT.<sup>51</sup> In this study, however, teeth were not

randomly allocated to the groups with or without crowns, and it may be that bias existed due to the selection of teeth with a better prognosis for crown restorations.

When endodontic failure occurs following primary RCT, nonsurgical retreatment is generally indicated, provided that the root canals are accessible (Fig. 1). Surgical treatment is a valuable alternative if nonsurgical retreatment is not successful, not indicated (for example, when primary treatment can be performed under the best possible conditions), or not feasible (particularly in teeth with root canal obliterations, or adhesively cemented posts, and teeth with alterations of the natural course of the root canal, such as ledge formation from previous treatment).<sup>9</sup> The prognosis for apical resection is less favorable if the tooth is not retreated nonsurgically in advance and if there is the possibility of an infection persisting in the root canal system (Fig. 1). Additional factors for a reduced prognosis for periapical surgery are: poor accessibility in the molar region, a persisting lesion despite apparently satisfactory RCT, lesion size  $\geq 5$  mm, coronal leakage, and surgical retreatment.<sup>55-57</sup> Surgical intervention is probably not worthwhile when the prognosis for periapical surgery is limited. The buccal fenestration created to gain access to the periapical area may not heal with an intact bony plate, so that the site is compromised, which may make additional bone grafting necessary before further implant treatment can be performed.<sup>58</sup>

#### Implant aspects

Dental implants are generally placed into relatively healthy surroundings (Fig. 2). This is clearly a different situation from that presented with periodontally involved or endodontically treated teeth, which require a different type of treatment evaluation. Following successful implant osseointegration, the prognosis is defined to be good when the im-

plant is functional intraorally without clinical or radiographic signs of bone loss or mobility (Table I). While initial implant fixation following placement is simply derived from mechanical stabilization, osseointegration with an intimate contact between the living bone and the titanium surface requires several weeks for direct bone apposition on the implant surface and subsequent structural adaptation in response to mechanical load.<sup>59,60</sup> Early implant failures occur primarily during the first weeks or months after implant placement and are frequently related to surgical trauma, complicated wound healing, insufficient primary stability, and/or initial overload.<sup>61,62</sup> Late implant losses occur after initially successful osseointegration and are caused by microbial infection, overload, or toxic reactions from implant surface contamination, such as from acid remnants.

Occlusal overload of an osseointegrated implant occurs when the load-bearing threshold set by the biological phenomenon of osseointegration is exceeded. Little is known about this individual limit and the potential influencing factors such as bone quality, implant surface modifications, and the type and direction of forces. While clenching exerts primarily vertical forces, bruxism creates excessive lateral forces, which are thought to be less well tolerated.<sup>63</sup> Overload results in a sudden loss of osseointegration with implant mobility (hopeless prognosis, Table I),<sup>64,65</sup> whereas microbial infection initiates periimplant mucositis.<sup>66,67</sup> This corresponds to gingivitis and may progress into periimplantitis, which corresponds to periodontitis.<sup>66</sup> While periimplant mucositis is a reversible inflammatory reaction in the soft tissues surrounding an implant, periimplantitis is an inflammatory reaction associated with loss of supporting bone around an implant in function.<sup>68</sup> Therefore, periimplantitis is clinically diagnosed by bleeding on probing (and/or sup-puration) in combination with radio-

graphic bone loss. Once diagnosed, the prognosis for the implant is questionable (Table I).<sup>69</sup> In sites affected by periimplantitis, the therapies usually applied attempt to resolve the infection, but these measures are not predictably successful in achieving reosseointegration in the previously contaminated region.<sup>70,71</sup> If the infectious disease remains untreated and progresses, implant mobility occurs, as soon as the apical portion of the implant osseointegration is affected.<sup>62</sup> There is no treatment modality to save a mobile implant, and the risk of further implant losses in patients who have experienced an implant failure increases by 30%.<sup>72</sup>

There are few absolute and definitive implant contraindications, but several provisional restrictions exist, such as incomplete cranial growth (Table II).<sup>9,73</sup> In young adults requiring single tooth replacement in the maxillary anterior region, implant placement should be postponed until after the age of 25 due to the changes in anterior face height and posterior rotation of the mandible that occur in this age group, particularly in women.<sup>74</sup> This continuous alveolar bone development may entail a vertical infraposition of the implant with the mucosal margin located too far apically with, as a result, significant esthetic effects. In situations with an enhanced risk of implant failure (such as in heavy smokers, patients with a history of aggressive periodontitis, or patients under intravenous bisphosphonate medication for more than 2 years), tooth preservation is preferred and extraction and further implant surgery is avoided.<sup>73,75</sup> In contrast, in patients with high caries activity, possibly related to having a dry mouth, less effort should be made to maintain a questionable tooth, and implant treatment may be favored. A dry mouth is a common side effect of several medications (such as antihypertensives, diuretics, antidepressants, atropine, anticonvulsants, anticholinergics used as spasmolytics, and appetite suppressants)

**TABLE II.** Contraindications and increased risk of implant failures (modified from Zitzmann et al<sup>9,73</sup>)

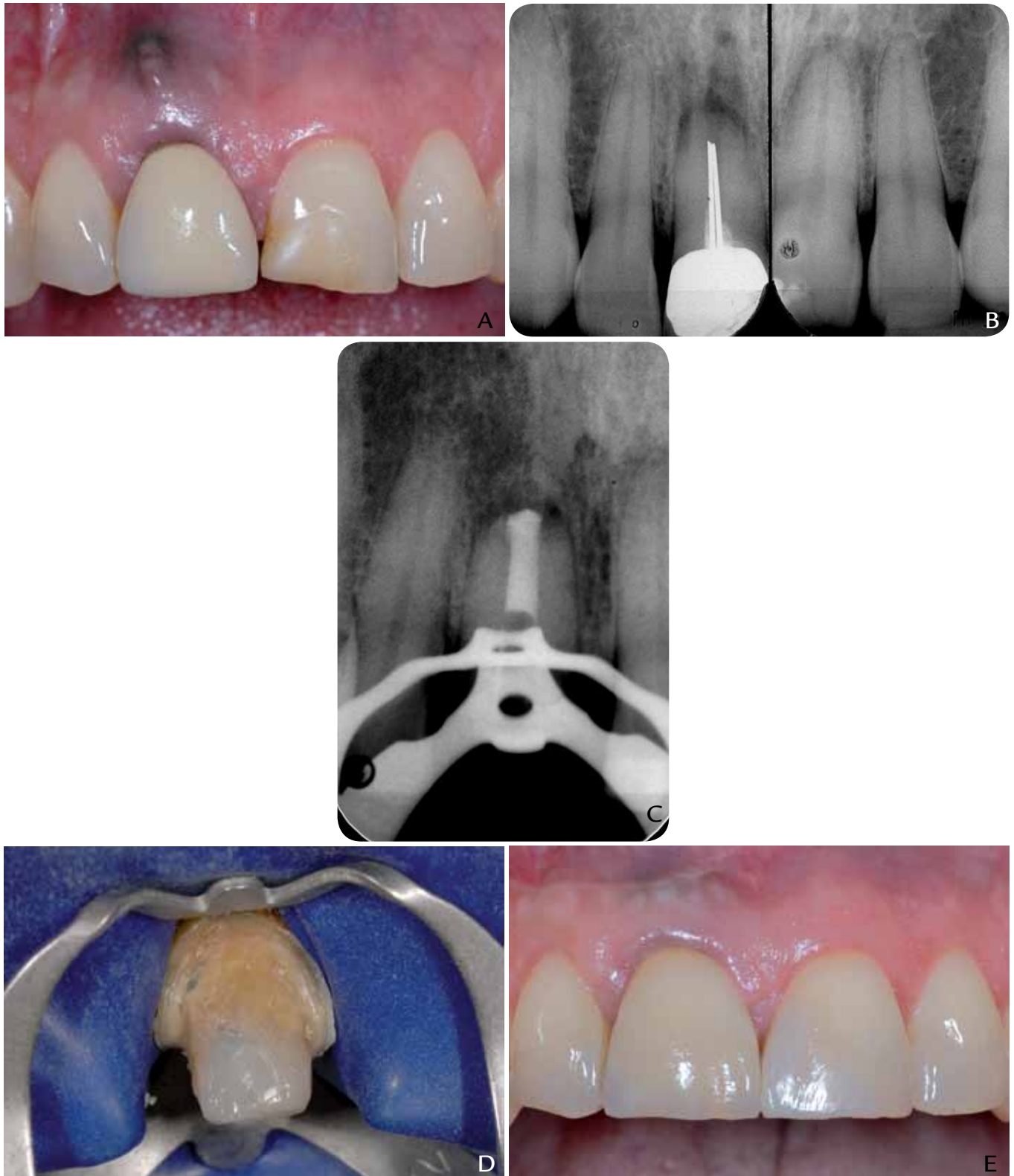
|                                                    | <b>Disease</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | <b>Assessment</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
|----------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Medical contraindications                          | <ul style="list-style-type: none"> <li>• Acute infectious disease</li> <li>• Cancer chemotherapy</li> <li>• Systemic bisphosphonate medication (<math>\geq 2</math> years)</li> <li>• Renal osteodystrophia</li> <li>• Severe psychosis</li> <li>• Depression</li> <li>• Pregnancy</li> <li>• Incomplete cranial growth with incomplete tooth eruption</li> </ul>                                                                                                                                                                  | <ul style="list-style-type: none"> <li>• Absolute, but provisionally; wait for recovery</li> <li>• Absolute, but provisionally; reduced immune status</li> <li>• Risk of bisphosphonate-induced osteonecrosis (BON)</li> <li>• Increased risk of infection, reduced bone density</li> <li>• Absolute; risk of reaction to implant as foreign body and requesting removal despite successful osseointegration</li> <li>• Relative</li> <li>• Absolute, but provisionally; to avoid additional stress and radiation exposure</li> <li>• Relative, but provisionally; to avoid any harm to growth plates, to avoid inadequate implant position in relation to residual dentition; use hand-wrist radiograph to evaluate end of skeletal growth; single tooth implants in anterior region not before 25 years of age</li> </ul>                                                                                                                                                                                                                                    |
| Intraoral contraindications                        | <ul style="list-style-type: none"> <li>• Pathologic findings at oral soft and/or hard tissues</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                           | <ul style="list-style-type: none"> <li>• Provisional restrictions; increased risk of infection, wait until healing is completed</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| Increased risk of implant failure or complications | <ul style="list-style-type: none"> <li>• History of (aggressive) periodontitis</li> <li>• Heavy smoking <math>\geq 10</math> pack-years (particularly in combination with HRT/estrogen), alcohol and drug abuse</li> <li>• Insufficient oral hygiene</li> <li>• Uncontrolled parafunctions</li> <li>• Post head and neck radiation therapy</li> <li>• Osteoporosis</li> <li>• Uncontrolled diabetes</li> <li>• Status post chemotherapy, immunosuppressants or steroid long-term medication, uncontrolled HIV infection</li> </ul> | <ul style="list-style-type: none"> <li>• Relative, requires supportive periodontal care; increased risk of developing periimplantitis</li> <li>• Relative or absolute, indicates cessation protocol; wound healing problems, locally reduced vascularization, impaired immunity, reduced bone turnover</li> <li>• Absolute; wound healing problems, infection</li> <li>• Relative; increased risk of technical complications</li> <li>• Absolute, but provisional restrictions; reduced bone remodeling, risk of osteoradionecrosis, implant placement 6-8 weeks before or <math>\geq 1</math> year after radiotherapy</li> <li>• Relative; reduced bone-to-implant contact; consider calcium substitution, prolong healing period, and avoid high torque levels for abutment screw fixation</li> <li>• Relative, requires medical treatment; wound healing problems (impaired immunity, microvascular diseases)</li> <li>• Absolute, but provisional restrictions; wound healing problems, medical advice required (consider corticosteroid cover)</li> </ul> |

and is also associated with several syndromes, such as Sjögren's.<sup>73</sup>

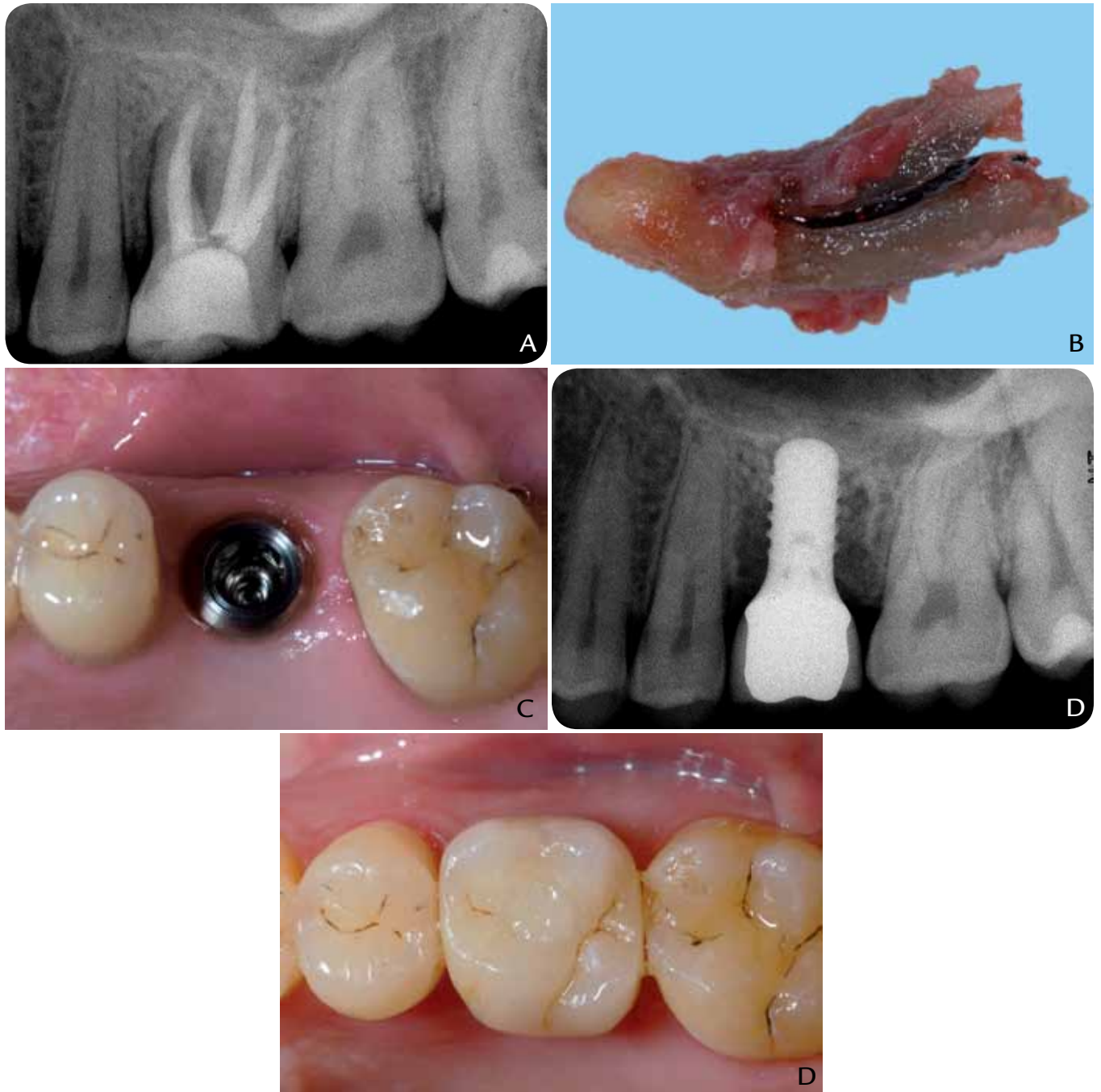
Intraoral contraindications for implant placement are rare and comprise pathologic findings of the soft and/or hard tissues that should be treated before implant placement is considered (Table II). Insufficient bone volume, particularly in patients with advanced periodontal attach-

ment loss, may interfere with the intended implant position (see "Periodontal aspects" section). There are several augmentation techniques applicable to enhance the bone volume during implant placement or in a staged approach, such as guided bone regeneration (GBR), autogenous bone grafts (such as inlay, onlay, or interpositional grafts), distrac-

tion osteogenesis, ridge splitting, and lateral antrostomy for sinus grafting. Alternatively, in the severely resorbed posterior mandible, nerve repositioning can be performed to facilitate implant placement. In a recent review of different augmentation techniques, it was observed that only 14% of the studies compared grafted sites to control groups, indicating a possible



**1** A, Initial clinical situation with 30-year-old crown on maxillary right central incisor with buccal fistula. Apical resection without previous nonsurgical retreatment by general practitioner was unsuccessful. Patient refused implant therapy. B, Radiographic view with silver points in place and periapical lesion. C, Endodontic retreatment. D, Situation after post placement and foundation placement. E, Clinical situation after cementation of metal ceramic crown (maxillary right central incisor) and composite resin restoration (maxillary left central incisor).



**2** A, Radiographic view of maxillary molar 12 years following endodontic treatment. Patient reports intermittent symptoms. Clinical examination reveals increased probing pocket depth on mesiobuccal site. B, Extracted mesiobuccal root shows fracture. C, Dental implant placed 3 months following extraction. D, Radiograph. E, Clinical situation after placement of screw-retained single crown. Screw access restored with white gutta-percha and composite resin.

influence of confounding variables.<sup>76</sup> For alveolar ridge augmentation techniques, detailed documentation and long-term follow-up studies were missing (with the exception of GBR with nonresorbable membranes). It was assumed that these procedures are more sensitive to the technique used and the operator's experience, with implant survival depending, at least in

part, on the amount of residual supporting bone.<sup>76</sup> When limited bone volume indicates bone augmentation procedures, this potential need for additional surgical interventions must be discussed with the patient, particularly as much more time for treatment is required, the treatment costs are higher, postoperative pain may be greater, and implant survival is possibly impaired.

Prosthodontic aspects

From a prosthetic perspective, the most decisive factor for tooth maintenance or extraction is the remaining coronal tooth substance and the strategic value of the respective tooth with regard to the residual dentition and the patient's preferences. As indicated by in vitro studies, the progn-



sis for the abutment tooth is assumed to be good if sufficient retention is provided by the presence of an appropriate total occlusal convergence angle (15-20 degrees conical) and 3- to 4-mm wall height.<sup>77-79</sup> In endodontically treated teeth, sufficient resistance form is assumed when a circumferential ferrule of at least 1.5 mm of tooth structure is present.<sup>10,80,81</sup> The prognosis is, however, questionable with reduced tooth structure that does not provide sufficient retention and resistance form, and the prognosis is hopeless with insufficient tooth substance if crown lengthening or extrusion are not applicable (Table I).<sup>58</sup> It must be noted that the criteria for ideal retention form were originally defined on the basis of *in vitro* studies investigating gold alloy restorations luted with zinc phosphate cement, while the use of adhesive cementation techniques potentially allows for greater flexibility.<sup>78</sup>

As soon as restorative therapies are required, all facets of periodontal, endodontic, and restorative risks must be considered, and possible implant contraindications evaluated. It has been shown that as soon as one or more root canal-treated abutments is involved in an FDP, the survival rate after 20 years is reduced to 57%, as compared to 69% when the FDP consists of abutments with healthy pulps only.<sup>82,83</sup> According to a multivariate analysis of abutment failures (365 teeth with vital pulps, 122 root-filled teeth), other influencing factors besides root canal treatment were distal terminal position in the FDP, and advanced marginal bone loss, as initially assessed from radiographs. Several variables were stronger multivariately than bivariately, which indicates that a combination of risk factors is the most detrimental for the longevity of the restorations.<sup>84</sup>

When developing a treatment plan, tooth prognosis is first assessed and all pretreatment requirements are considered, including periodontal treatment, RCT, posts and cores, crown lengthening, and/or ortho-

odontic extrusion. Before the definitive restorative therapy is conducted, any questionable tooth is reevaluated in terms of periodontal stability, unaffected sensibility, or healing of periapical radiolucency following RCT. As soon as multiple risk factors are identified for a tooth intended as an abutment for an FDP, complexity increases and the entire restoration is at higher risk. As long as the planned restoration is a single crown in an otherwise intact arch (Fig. 1), a questionable tooth with an increased risk might be accepted, particularly when the implant alternative requires additional augmentation procedures that the patient prefers to avoid (see "Implant aspects"). When, however, the questionable tooth is in a strategic position for a long-span FDP, extraction and a change in treatment plan with single units or short-span FDPs supported by implants or teeth may be considered. Clearly, the condition of the remaining dentition and the overall treatment plan will determine, at least in part, whether or not a questionable tooth is maintained. Therefore, a tooth with a relatively good prognosis, but requiring several pretreatment procedures, may be extracted as soon as the adjacent teeth (or implants) require restorations; this can be done at lower risks and costs as the single tooth prognosis may be overruled by the treatment decision and the risk assessment made for the entire restoration. This is supported by literature showing that after introducing implant-supported restorations as a treatment option, the number of long-span FDPs was reduced and the overall failure rate of tooth-supported FDPs decreased from 4% to 2% after 5-10 years.<sup>85,86</sup> Using less compromised teeth as abutments, not necessarily extracting and replacing them, but placing implants in addition, facilitated an improved outcome for tooth-supported FDPs.<sup>86</sup> According to a review comparing the outcome of implant- and tooth-supported restorations, there were no differences after 60 months, with

a 95% success rate for implant restorations and 94% for conventionally fixed dental prostheses, while resin-bonded FDPs had a somewhat lower success rate of 75%.<sup>87</sup>

Considering esthetic aspects in the anterior region has also become increasingly important for the periodontal and endodontic disciplines, primarily in terms of recession and discoloration, but it is crucial as soon as restorative therapies are required.<sup>5,11,58,88</sup> The preservation of gingival structures is critical and is most predictable when the questionable tooth is treated and maintained with a sound periodontium. As soon as tooth extraction is performed, most of the distinct fiber arrangements within the zone of connective tissue attachment are lost, particularly those inserting into the cementum (such as dentogingival, circular, transseptal fibers).<sup>89</sup> In single tooth spaces, the gingival architecture may be preserved by the fiber arrangements associated with the adjacent teeth (such as interpapillary, intercircular, transgingival fibers).<sup>89,90</sup>

It was previously believed that implant placement in the fresh extraction socket (immediate implant placement) would prevent bone resorption and, hence, maintain the original shape of the ridge.<sup>91</sup> A recent clinical study has demonstrated, however, that irrespective of the placement of an implant, postextraction bone remodeling occurs and results in horizontal and vertical bone loss.<sup>92</sup> According to a review with accompanying guidelines, buccal gingival recession has also been observed following immediate implant placement.<sup>93</sup> This procedure should not be the treatment concept of choice for patients with a thin-scalloped gingival biotype.<sup>93</sup> Associated characteristics in patients with a thick biotype are square-shaped teeth and flat papillae, while those with a thin gingival biotype present with more triangular-shaped teeth and long papillary structures. In high-risk patients with a thin biotype, a staged implant procedure is

more predictable and therefore preferable.<sup>94</sup> Alternatively, reconstructive treatment options can be considered. In contrast, the risk for esthetic failure with implants may be limited in patients with a thick, flat biotype.<sup>58,94</sup>

In a recent review investigating the outcome of immediately loaded implants with single crowns, a higher failure risk was found for immediate loading than for conventional loading (3 to 6 months of healing).<sup>95</sup> Although no or only minimal occlusal contact was established in all except one of the studies included, all authors reported a higher failure rate for the immediately loaded group, and indicated flapless placement, functional load, placement in fresh extraction sockets, or insufficient primary stability to be possible contributing factors for failure in osseointegration.<sup>95</sup>

## SUMMARY

The different aspects related to the long-term success and survival of implants and periodontally involved, endodontically treated, and/or prosthetically compromised teeth imply that:

1. After successful periodontal treatment, teeth with reduced periodontal support are capable of serving as foundations for single crowns or as abutments for FDPs; however, maxillary molars and resected mandibular molars with retained mesial roots are the teeth most likely to be lost.

2. Most failures following endodontic treatment are related to nonendodontic factors, such as periodontal disease, recurrent caries, improper reconstructions, crown fracture, or root fracture at the level of the post.

3. Most failures caused by endodontic factors are managed by orthograde retreatment and/or surgical interventions.

4. Most implant failures are associated with impaired osseointegration and require implant removal.

5. From a restorative perspective,

the amount of remaining coronal tooth substance is critical for the strategic value of an abutment.

6. For complete-mouth restorations, it is recommended to use dental implants strategically, to plan smaller units (short-span FDPs), either tooth or implant supported, and to include only abutments with a good prognosis for long-span FDPs.

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