Criteria to Maintain Periodontally-involved Teeth versus Extract and Replace with Implants: A Delphi Study

A Thesis

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By

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Abstract

Objective

The purpose of this study was to investigate the clinical criteria periodontists consider to maintain a periodontally-involved tooth versus replacement of the tooth with an implant. Decision-making criteria were investigated using a Delphi study.

Materials & Methods

A questionnaire was developed by the Division of Periodontology to determine which factors are important in the decision to maintain a tooth or extract it and replace it with an implant. More specifically, periodontal factors, general clinical factors, and patient-centered factors were considered important criteria to investigate. Using the Delphi method, two rounds of questionnaires were mailed to prescreened, active Diplomats of the American Board of Periodontology in the United States, who had agreed to participate. Responses were analyzed and results presented as frequencies or averages, depending on the data that were collected.

Results

25 periodontists agreed to participate and 12 completed both rounds of questionnaires. The two most important factors for replacement of teeth with dental implants, in order, were identified as bone loss and tooth mobility. Minimum criteria for bone loss and tooth mobility that would result in extracting and replacing a tooth were: 70% bone loss with no tooth mobility; 60% bone loss with Grade 1 or 2 tooth mobility; 40% bone loss with Grade 3 tooth mobility; probing depth of at least 7 mm, and Grade III furcation involvement. When planning an implant case, panelists were concerned primarily about esthetics for anterior teeth, malocclusion for posterior teeth, and patient satisfaction. Treatment costs were not a major concern.

Conclusion

The clinical criteria for implant placement suggest that periodontists select removal of teeth that are significantly affected by periodontal disease.

Vita

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Gordon, R. Parashis, A. Tatakis, D. Extraoral uses of autologous oral soft tissue grafts: a different bridge between mouth and body health. Clinical Advances in Periodontics, 2017. 0: p. 1-12. doi:10.1902/cap.207.160076

Fields of Study

Major Field: Dentistry

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Chapter 1: Introduction

1.1 Background

Dental implants are an increasingly popular treatment option for replacing missing, non-restorable, and periodontally-involved teeth. General dentists and dental specialists placed more than 5.5 million dental implants in the United States in 2006. Additionally, the American Academy of Implant Dentistry estimated that the dental implant market will reach $6.4 billion by 2018[1]. With numerous reports of favorable long-term success rates, dental implants have established a strong presence in dental offices around the country[2]. However, this increase in placement does not come without consequence as the reported prevalence of peri-implantitis was estimated to affect as many as 47% of dental implants[3, 4]. Management of the growing disease burden is not without its own challenges, as the long-term outcome of peri-implantitis treatment is largely unpredictable[5-7]. Therefore, the dental practitioner must make an informed decision, that is, appreciate the risks versus benefits, prior to offering implant therapy.

The consideration for implant therapy is relatively straightforward for a patient demonstrating missing or non-restorable teeth. In contrast, decision-making for replacing a tooth affected by periodontal disease is difficult. Corn described this dilemma in regard

to periodontal treatment in 1969, coining the term “strategic extraction”. The objective was to evaluate the prognosis and prosthetic value of both the offending tooth and the adjacent teeth to determine the most stable comprehensive treatment[8]. Prior to dental implants, these strategies often revolved around periodontal, endodontic and prosthodontic methods. By the 1980s, the topic of strategic extraction was complicated by the emergence of the modern endosseous implants as introduced by Branemark[9]. Periodontology textbooks revisited this concept with the rise of implantology, yet shed only scant clarity on how to best incorporate dental implants into periodontal practice[10]. This challenge has only progressed as recent longitudinal studies demonstrated that patients with a previous history of periodontitis have a higher risk of developing peri-implantitis[11, 12]. Furthermore, a systematic review by Levin revealed that periodontally-involved tooth survival and implant survival remained relatively similar after fifteen years (3.6-13.4% vs. 0-33%, respectively)[13]. It would appear that the tissues supporting dental implants and the tissues supporting teeth are both susceptible to disease. However, under the appropriate circumstances, they are capable of long-term resilience; an unequivocal winner has yet to emerge. A recent commentary by Richard Kao has highlighted the continued difficulty in determining the proper place for implants in periodontal therapy, describing it aptly as a “paradigm shift that is changing our profession”[14].

Several authors have offered insight into the decision over when to maintain periodontally-involved teeth versus remove and replace them with implants[15-18]. A case

series by Lundgren et al. described ten patients with severe chronic and aggressive periodontitis treated with comprehensive periodontal therapy showing successful long-term tooth retention for more than eighteen years. He stated “the natural tooth should not be considered an obstacle but a possibility, whether or not the treatment is to include implant installation”[16]. Avila et al. developed a decision-making process to aid practitioners regarding tooth retention or extraction based on previous periodontal literature. Their model scores patient and clinical factors, specifically, esthetics, finances, compliance, probing depth, mobility, abscesses, bone loss, defect morphology, degree of furcation involvement, etiologic factors, restorative factors and other determinants to assess whether long-term maintenance is “unfavorable”, “caution recommended” or “favorable”[17]. The portions of the model specific to periodontally-involved teeth is based on extensive evidence regarding the prognosis of teeth with increased probing depths, bone loss, mobility and furcation involvement. A review by Donos et al. approached this topic in question-and-answer format, again emphasizing the literature supporting long-term retention of periodontally-involved teeth[18]. They recommend a combination patient and site risk assessment to help predict their susceptibility to implant complications, to include bone loss, periodontal probing depths, tooth anatomy, furcation involvement, and tooth mobility[18]. However, there were almost no definitive recommendations made regarding the sparse quantitative information received from a periodontal examination.

The literature evaluating periodontal disease progression and prognosis may be partly responsible for the variability seen among contemporary decision-making guides.

Severe periodontitis and tooth loss appear in a subset of the population, with milder forms prevalent in more than a third of the U.S.[19, 20] Periodontal treatment and maintenance are beneficial to maintaining teeth in periodontally-involved patients, and have been estimated to cut annual tooth loss rates in half[21, 22]. However, the identification of these high risk patients remains rather empirical[23]. Historically, periodontal prognostic systems were relatively weak in identifying teeth with poor periodontal prognoses. An early prognostic system established by McGuire & Nunn predicted 5-year and 8-year prognoses 81% of the time, but only 50% when teeth with "good" prognoses were excluded[24]. Based on these findings, periodontists may be as accurate at determining the prognosis of moderate-to-severe periodontally-involved teeth as correctly as calling a coin toss.

Other systems have also emerged with limited prospective predictability regarding teeth with advanced periodontal disease[25, 26]. A study by Miller et al. examined the long-term retention of furcation-involved teeth in patients with moderate-to-severe periodontitis. Their retrospective study found that more than 67% of molars given the worst prognosis were maintained after fifteen years[27]. A recent review examined clinical trials addressing the ability of common periodontal parameters to forecast disease progression prior to implant treatment planning[28]. Their results conclude that no single parameter can effectively determine periodontal disease activity or predict tooth loss. Rather, the absence of inflammation and a stable periodontium appear to be necessary for tooth retention. They concluded that "presently, there is no precise way to delineate a

quantifiable threshold for tooth removal based on periodontal status that is correct in every circumstance… The decision to extract a tooth will fluctuate depending on its clinical condition…"[28]. Currently there are no evidence-based decision-making guides concerning this dilemma, and little is known regarding clinical recommendations exercised by dental implantologists in the U.S. Using the results of a Delphi study, this project developed guidelines for dental practitioners who are facing the decision whether to keep and treat a periodontally-affected tooth or extract and replace it with an implant.

1.2 Delphi Survey

The Delphi method uses a series of questionnaires, with feedback, to allow a group of experts to form a consensus regarding a complex problem[29]. The process takes its name from the ancient Delphic oracle's skills of interpretation and foresight. It is one of the most commonly used techniques in medical and health services research for synthesizing information when published information is lacking or non-existent[30]. Traditionally, a Delphi survey includes open-ended questions with subsequent rounds of questions focusing on the most common response. An alternative method is to present a structured questionnaire developed by reviewing literature for the initial round and give feedback to the panelists, in subsequent rounds, on the most common responses[31]. Rounds are typically conducted until there is stability of the questionnaire answers. This typically requires two to three rounds[32]. Another important aspect of the Delphi method is the expert panel. Few guidelines exist regarding the development of a Delphi panel. It is

suggested that it includes a diverse array of experts on the topic of choice, and the panelists should be willing to participate in all questionnaire rounds in order to make the outcome valuable[29]. A representative selection of expert panelists is preferred, and the definition and selection process of such experts should be critically reviewed[30]. There are also no specific guidelines regarding the proper size of a Delphi panel. Although a larger panel might be better, the size of the panel may be limited by the topic, time and resources[33].

Although the validity of the Delphi method has come under question with regard to its reliability, bias in panelist selection, and lack of participant discussion, other reviews show no clear evidence that other meeting-based methods reign over the Delphi method[30]. According to Rowe, while the Delphi survey is generally inferior to other consensus techniques, the degree of inferiority is minimal, and its use arises more from practicality than fundamental differences[34]. In spite of criticism, the Delphi survey offers several advantages; mainly that it is a relatively fast, anonymous, and inexpensive method at forming a consensus[35]. Consensus from previous studies range from 55-100% agreement, however the results are frequently left open to interpretation with the reporting of the final responses[36, 37]. Inherently, the Delphi survey represents expert opinions rather than quantitative data and, thus, the outcomes of the survey need formal validation by additional research[38].

1.3 Research Goal

- Formulate a consensus on criteria to replace periodontally-involved teeth with dental implants.

1.4 Specific Aims

- Determine a hierarchy of criteria used by practitioners to decide tooth retention versus replacement with a dental implant
- Determine the amount of change in clinical factors associated with the decision for tooth retention versus replacement with a dental implant

Chapter 2: Materials and Methods

2.1 Panelists

Candidates for panel participation three pre-selection criteria. 1) They graduated from an accredited periodontal program in the United States; 2) had a minimum of five years of periodontal practice experience; and 3) were Active Members of the American Academy of Periodontology (AAP). Twenty-five periodontists (15 private practitioners, 8 academicians, 1 military person, and 1 organized dentistry officer) representing all regions of the United States, met the criteria and constituted the Delphi panel.

2.2 Exclusion Criteria

Panelists were excluded if they did not complete the survey, specifically requested to be removed from the study or, if their current address was not on file with the AAP.

2.3 Initial Letter

Prior to mailing the survey, an initial letter was mailed to prospective panelists (Fig. 1). This letter invited the candidates to join the study, defined and described the

components of the Delphi survey, and alerted them to the fact that they would be receiving our survey soon.

2.4 Construction of Questions

The survey included four questions. They were constructed by the investigators at The Ohio State University. A set of simple instructions to the panelist were also included (Fig. 2). Question 1 requested the panelists to consider the minimal necessary clinical findings to extract a tooth and replace it with an implant in regard to: (1) mobility and bone loss, (2) probing depth, and (3) furcation involvement (Figure 3 top). The values varied by the outcome rated. For each tooth mobility grade from 0 to 3 (Miller 1985), a bone loss value in percent was requested. For probing depth, a whole millimeter value was requested. For furcations, a minimal Grade (Glickman 1953) was requested.

Question 2 requested the panelist to consider the clinical findings that would prevent them from extracting a tooth and replacing it with an implant (Fig. 3 bottom). For plaque (Silness & Löe, 1964) and inflammation (Löe & Silness, 1967), a value of 1, 2, 3 or “not a factor” was requested. For smoking, a minimum number of cigarettes or “not a factor” was requested. For diabetes mellitus, a minimum glycated hemoglobin level (HbA1c) or “not a factor” was requested.

Question 3 (Figures 4 & 5) requested the panelist to estimate about how concerned they were regarding the following factors when planning to extract and replace a tooth: (1) requires root canal treatment, (2) previous root canal treatment requiring

retreatment, (3) malocclusion or parafunction, (4) esthetics, (5) pain, (6) patient satisfaction and (7) cost to patient. Question 3 was divided into two parts, i.e., question 3a and 3b referred to an anterior tooth (Fig. 4) and posterior tooth (Fig. 5), respectively. The panelist was requested to indicate the level of concern using a visual analog scale (VAS) in the form of a 100 mm horizontal line with two anchor points at each end. The left anchor point indicated a panelist is "not concerned" about this factor, while a right anchor point indicated they are "extremely concerned" (Figs 4 & 5). The distance from the left anchor point was measured (mm) and divided by 100 to assign a percent value.

Question 4 (Figure 6) requested the panelist to rank their top three factors from most important (1) to second most important (2) to third most important (3) when planning to extract a tooth and replace it with an implant. The panelist was given a list of the following factors: (1) bone loss, (2) cost, (3) esthetics, (4) furcation involvement, (5) gingival inflammation, (6) pain, (7) patient satisfaction, (8) plaque control, (9) probing depth, (10) malocclusion or parafunction, (11) mobility, (12) requires root canal treatment, (13) previous root canal treatment requiring retreatment, and (14) smoking status. An additional space was provided for panelists to indicate a factor not otherwise listed.

2.6 Instrument: Round 2

Following tabulation of the data from the first round, a second survey was developed. This survey included a new set of instructions (Fig. 7). The same questions

were used in the surveys of round 1 and round 2. However, the most frequent responses from the first round were highlighted in red font for questions 1 and 2 (Fig. 8). For questions 3a and 3b, the average distance of the VAS was indicated by a red line (Figs. 9 & 10).

Finally, in question 4 (Figure 11), the list of factors was rearranged according to the factors' importance score resulting from round 1. In addition, the most frequent "most important" and "second-most important" factors were indicated by a red "1" and "2" next to the factor, respectively. Due to the variability regarding the "third-most important" factor, the most common "third-most important" factors were indicated by "3*".

The panelists were requested to complete the survey, considering the most frequent responses from the first round. If they agreed with the most frequent response from the first round, they were asked to circle it. If they disagreed, they were asked to circle the answer they felt was most appropriate.

2.7 Mailing Protocol

An introductory letter was mailed to 25 panelists on October 13, 2016 and the first round of surveys was mailed October 20, 2016. All panelists were contacted by telephone to discuss the survey, answer any questions and determine if they were interested in participating. The cut off for returning the first round surveys was made on December 15, 2016. The second survey was developed and mailed on January 12, 2017,

and this survey was mailed out to the 18 panelists who returned their first survey. The cut off for returning the second round of surveys was made on April 11, 2017.

Both rounds of surveys were mailed to panelists using the United States Postal Service. All surveys were returned to the department secretary via the United States Postal Service who then forwarded the survey for data collection. A randomized number was assigned to each panelist, and removed and recorded after receipt of the completed survey, thereby unlinking the panelist from their response. If a panelist did not receive a survey or lost the initial mailing, a second survey was sent to them using an overnight service. These surveys were returned in the same fashion as described above.

2.8 Phone Calls

During data collection, all panelists received at least one phone call from the principal investigator or from the co-investigator. The majority of these phone calls were to remind panelists of return deadlines and clarify any questions they had.

2.9 Statistical Methods

Responses to question 1, 2 and 4 were expressed as frequencies represented by bar and/or pie charts. Responses to questions 3a and 3b were recorded using a VAS and summarized by a box-and-whisker plot with minimum, maximum, median, 25^{th} and 75^{th} quartiles indicated. For both 1^{st} and 2^{nd} rounds, results were tabulated from the 12 participating panelists. Consensus was defined as achieving agreement between more

than or equal to 75% of panelists, based on the median threshold of ninety-eight Delphi protocols[39]. If consensus was achieved for a particular question or criteria, it was dropped from the subsequent (2nd) round.

Chapter 3: Results

3.1 Panelists

Twenty-five periodontists agreed to participate in the study. They constituted the first-round panel. Eighteen of the 25 panelists returned the first questionnaire for a response rate of 72%. Of the 18 panelists who completed the first round, 12 returned the second questionnaire for a response rate of 67%. The overall response rate for completing both rounds was 48%. Data were analyzed on information obtained only from panelists who completed both rounds.

The final panel comprised 8 academicians, 3 private practitioners and 1 from the military. The average number of years in practice was 18.6. All participants were male and the average age was 52 years old. Five panelists served in leadership positions for the American Board of Periodontology, two are members of the Academy of Osseointegration, one served on the editorial board for the *International Journal of Oral and Maxillofacial Implants* and one authored several textbooks on clinical periodontics and implant dentistry.

3.2 Periodontal Findings

Figure 12 shows the responses from the first and second round concerning the threshold level for % bone loss and tooth mobility that triggers tooth extraction and replacement with an implant. In the first round, a plurality (42%) of panelists selected 70% bone loss for a tooth with no mobility (Fig. 12, Panel a). In the second round, a majority (67%) of panelists selected 70% bone loss for a tooth with no mobility (Fig. 12, Panel a). A plurality (33%) of panelists selected 60% bone loss for a tooth with Grade 1 or 2 mobility in the first round (Fig. 12, Panels b and c). In the second round, a plurality (42%) selected 60% bone loss for a tooth with Grade 1 mobility (Fig. 1, Panel b) and a majority (75%) of panelists selected 60% bone loss for a tooth with Grade 2 mobility (Fig. 12, Panel c). Finally, a plurality (27%) of panelists selected 40% bone loss for a tooth with Grade 3 mobility in the first round (Fig. 12, Panel d), however a majority (58%) of panelists selected 40% bone loss for a tooth with Grade 3 mobility in the second round (Fig. 12, Panel d).

All four mobility categories showed increasing agreement from the first round to the second round, with a majority response existing for non-mobile (70% bone loss), Grade 2 mobile (60% bone loss), and Grade 3 mobile (40% bone loss) teeth. Consensus was achieved for the following criteria ranges in the second round: no mobility and ≥70% bone loss (11 out of 12 panelists), Grade 1 mobility and ≥60% bone loss (11 out of 12

panelists), Grade 2 mobility and ≥60% bone loss (11 out of 12 panelists), and Grade 3 mobility and ≥40% bone loss (9 out of 12 panelists).

The frequency responses for other periodontal criteria necessary to extract a tooth and replace it with an implant are shown in Figure 13. A plurality (33%) of periodontists selected a 7 mm probing depth in the first round, which increased to a majority response (58%) in the second round (Fig. 13, Panel a). For furcation involvement in the first round, 50% of periodontists selected Grade II (Fig. 13, Panel b) and 50% selected Grade III (Fig. 13, Panel b) furcation involvement. In the second round, a majority of panelists selected Grade III (83%) furcation involvement (Fig. 13, Panel b).

For PlI, a majority (58%) of panelists indicated it was not an applicable index for extraction, and the decision not to include PlI increased to 100% in the second round (Fig. 13, Panel c). Similar results were seen for GI. Half of the responses indicated that it was not an applicable index in the first round, increasing to consensus at the second round (100%; Fig. 13, Panel d). For cigarette smoking and HbA1c, the second round had majorities indicating that smoking 10 or more cigarettes per day (83%; Fig 13, Panel e) or an HbA1c level greater than 8% (75%; Fig 13, Panel f) were criteria that would prevent extraction and replacement with an implant.

3.3 Clinical Findings

All responses for anterior teeth demonstrated an increasing trend toward consensus from the first to second rounds as confirmed by the decreased interquartile

variation and range. In addition, the median did not change substantially from first to second round, thus supporting the notion of consensus formation (Fig. 14). Patient satisfaction remained the factor that panelists were most concerned about for anterior teeth at both rounds (medians: 87% in both first and second rounds; Fig 14, Panel f), followed closely by esthetics (median: 87% / first round and 86% / second round; Fig 14, Panel d). Panelists were least concerned about anterior teeth needing root canal treatment in the second round (median: 19%; Fig. 14, Panel a).

All responses for posterior teeth demonstrated an increasing trend toward consensus from the first to second rounds, except for esthetics, which retained a similar interquartile range and minimum/maximum values (Fig. 15, Panel d). Patient satisfaction was the factor that panelists were most concerned about for posterior teeth (median: 74% / second round; Fig. 15, Panel f), followed closely by malocclusion (median: 72% / second round; Fig. 15, Panel c). Panelists were least concerned about posterior teeth needing root canal treatment in the second round (median: 23%; Fig. 15, Panel a).

3.4 Significant Factors for Extraction and Replacement

The panelists were asked to rank the factors they believed were important for extracting a tooth and replacing it with an implant. Bone loss received the most combined responses regarding importance. More specifically, a majority (75%) of panelists included bone loss as either the 1st, 2nd or 3rd most important factor in the first round (Fig. 16, Panel a), which then increased to 83% in second round (Fig. 16, Panel b). Bone loss

was selected as the most important or number one factor for tooth removal and replacement (50% / first round, Fig. 16, Panel a; 50% / second round, Fig.16 Panel b). Mobility was the second-most frequently selected response (Fig. 16, Panel a; Fig. 16, Panel b). Mobility showed the greatest increase in combined responses from the first to second round, with 33% of panelists including mobility as either the 1st, 2nd or 3rd most important factor in the first round (Fig. 16, Panel a) and 58% of panelists indicating so in the second round (Fig. 16, Panel b). A significant level of importance in clinical decision making also included smoking (50%; Fig. 16, Panel b) and esthetics (42%; Fig. 16, Panel b). When the responses were weighted in regard to most-frequent responses, to second-most frequent response to third-most frequent response, the hierarchy of selections changed in that the third-most important aspect was esthetics instead of smoking (Fig. 16, Panel c).

Discussion

4.1 Research Goal

Our research goal, to achieve consensus on criteria used to maintain a periodontally-involved tooth or extract it with an implant, was met for some, but not all, individual factors. The panelists achieved consensus for two minimum criteria when choosing to extract and replace a tooth with an implant: Grade 2 mobility with 60% bone loss and Grade III furcation involvement. The panelists also achieved consensus for four clinical factors that would prevent them from extracting a tooth and replacing with an implant, specifically, PlI (not applicable), GI (not applicable), smoking more than 10 cigarettes/day, and a glycemic control greater than 8% HbA1c. With regards to our specific aims, we determined that bone loss and mobility are the top two factors, respectively, panelists consider in the decision to either maintain a tooth or replace it with an implant. Additionally, when including responses with greater or more severe values than the most common threshold, all clinical & periodontal criteria achieve consensus agreement.

4.2 Panelists

The 12 panelists included in this study were representative of experts in periodontology and implantology. All panelists were board certified by the AAP and

many have leadership positions and expertise in implantology. The majority of panelists were academicians, while a minority consisted of private practitioners and military. Since the Delphi protocol has no established minimum or maximum number of panelists, the emphasis is on gathering a critical mass of experts able to arrive at a consensus.

4.3 Periodontal Findings

A majority of panelists agreed on all periodontal findings for a minimum threshold that would be necessary to consider extracting a tooth and replacing it with an implant. The minimum bone loss necessary to extract a tooth decreased with increasing tooth mobility, i.e. 70% for no mobility, 60% for Grade 1 or 2 mobility and 40% for Grade 3 mobility. Additionally, a majority of panelists agreed that a minimum 7 mm probing depth and Grade 3 mobility were necessary for implant consideration. These results suggest that these experts were only considering implants for severely involved teeth. In agreement with a previously published decision tree for tooth retention versus implant placement proposed by Avila, these criteria were all identified as “unfavorable” for long-term tooth survival[17].

The two factors that arrived at unanimous agreement were plaque accumulation and gingival inflammation. The fact that all panelists agreed that both plaque and gingival inflammation were not applicable in the decision to extract teeth and replace with an implant is of interest and calls for additional information. One would expect these factors to be of high concern, especially with the growing literature establishing a history of

chronic periodontitis as a risk factor for peri-implantitis and implant failures[40] and the myriad of classical studies describing poor outcomes associated with periodontal treatment due to plaque-infected dentitions[41]. It is difficult to argue against the deleterious role plaque accumulation and inflammation play in periodontal and implant treatment, but maybe there is more behind this consensus. Is it that plaque accumulation and gingival inflammation are shown to be detrimental in any advanced treatment, i.e. surgical periodontal treatment or implant therapy, and, thus, the question at hand would not be considered at all? Is it the belief that these two factors have largely similar effects on the both tooth and implant survival and, therefore, are inconsequential? Most studies would refute this, as implant bone loss is usually more aggressive and there is currently no definitive treatment for peri-implantitis[16]. Whatever the rationale, shedding further light on the explanation would be of value.

Smoking is a known risk factor for periodontal disease and there is growing evidence that it is also true for peri-implantitis[42]. Smoking has strong evidence in longitudinal studies for its association with periodontal disease and has demonstrated dose-dependency coincident with higher risks for periodontitis[43, 44]. There is certainly a degree of host susceptibility that comes into play with regards to how harmful smoking is to the periodontium, as not all individuals that smoke have equivalent degrees of attachment loss[45]. This discrepancy has also become evident in peri-implantitis, i.e. there are likely individuals at higher risk of peri-implant disease when exposed to cigarette smoke[16]. Unfortunately, we are unable to reliably determine these high risk individuals

until it is too late. Practically, the question of how a practitioner determines this risk profile usually rests on the calculation of their historical pack-year consumption or current smoking status. We included smoking status in our questionnaire as a representative of a patient's current condition, to avoid confusion in the paucity of information regarding risk assessments of former smokers. It is not surprising, then, that most panelists did not favor a patient that was currently using ≥10 cigarettes a day.

Diabetes mellitus is a known risk factor for periodontitis[46], and more information is emerging regarding its effect on implants. Although the implant failure rates do not appear higher in uncontrolled diabetic versus non-diabetic patients[47, 48], recent meta-analyses indicate a higher risk of altered early bone healing, implant stability, peri-implant mucositis and peri-implantitis in diabetics[47, 49]. Diabetic patients are typically advised to achieve glycated hemoglobin (HbA1c) of ≤7% for orthopedic surgeries as the rate of surgical site infections decreases significantly at or below that level[50-52]. This is in agreement with our study, as the majority of panelists indicated an HbA1c of 8% or greater would prevent them from replacing a tooth with an implant.

4.4 Clinical Findings

There are a multitude of clinical factors that go into considering replacing a peridontally-involved tooth with an implant, but our study focused on seven common considerations, specifically: (1) teeth requiring a root canal treatment, (2) previously root canal treated teeth requiring retreatment, (3) malocclusion, (4) esthetics, (5) pain, (6)

patient satisfaction and (7) cost. For anterior teeth, it was not surprising that patient satisfaction and esthetics were the top two considerations, respectively, given the inherent visibility of this region. Similar regarding the distinguishing function of posterior teeth, panelists reported the greatest concern was for patient satisfaction, followed closely by malocclusion. Regardless of tooth position, providing a service that meets the patient's goals and expectations appears paramount in this decision. Understandably, esthetics received the lowest level of concern for posterior teeth.

The need for endodontic treatment remained of low concern to our panelists, likely reflecting the high long-term success rates of endodontically-treated teeth of more than 90%[53-55]. However, there was an increase in concern with previous endodontically-treated teeth requiring retreatment. The rise in concern for teeth requiring endodontic retreatment may be attributable to the lower reported long-term success rates versus primary endodontic therapy[56]. Pain and cost remained of moderate concern for both anterior and posterior teeth through both rounds of the Delphi survey.

4.5 Significant Factors for Extraction and Replacement

Strictly based on the most common responses for each rank, the top three factors for the decision to replace a tooth with an implant are (1) bone loss, (2) mobility and (3) smoking. Bone loss is the hallmark of periodontal disease and peri-implantitis, so it is not surprising that it received the most responses for the single most important factor in this decision. As there is conflicting information regarding the successful periodontal

treatment of mobile teeth[57, 58], it is also not surprising that mobility ranked as the second most important factor. As previously mentioned in the discussion, there is sufficient evidence to implicate smoking as a risk factor in periodontal and implant treatment. These results should come with caution, however, as there may be bias from Question 1 which may have primed panelists to consider that they are inherently important factors.

Additionally, there is difficulty in interpreting the results from categories receiving varying 1st-, 2nd- and 3rd-most important responses. For example, in Figure 16 (Panel b), "smoking" received six total responses while "esthetics" received five. However, the majority of responses for "smoking" were for the 3rd-most important factor, while "esthetics" received more 1st- and 2nd-most responses. We may appreciate this in Figure 16 (Panel c), which displays a weighted hierarchy of the most important factors indicated in the second round in the decision to extract a tooth and replace it with an implant.

4.6 Limitations

It is of note that these panelists may be less reflective of the demographic of the AAP as a whole, although their expertise in implantology is desirable for the purpose of the Delphi survey. There were significantly more academicians participating in this study than the national average (66%). Also, there was a significant underrepresentation of the Western region (8%). These discrepancies may be anticipated, however, as a Delphi survey is designed to seek out specific panelist as experts in the field of question. The

overall response rate may have been improved if an online format for the questionnaires could have been used. This would improve convenience for the panelists and remove any obstacles to receiving and returning the survey in a timely manner.

4.6 Conclusions

Using the Delphi method, an expert panel agreed that a tooth should be extracted and replaced with an implant if the following criteria are met: (1) 60% bone loss with Grade 2 mobility and (2) Grade III furcation involvement. The panel also agreed that a tooth should not be extracted and replaced with an implant if the patient: (1) smokes 10 or more cigarettes per day or (2) has a glycemic control of 8% HbA1c or greater. Overall, the clinical criteria for implant placement suggest that periodontists select removal of teeth that are significantly affected by periodontal disease, i.e. Grade 3 furcation, 70% bone loss on non-mobile teeth, 40% bone loss on severely mobile teeth and probing depths ≥7 mm. Periodontists do not consider local factors, like plaque accumulation or gingival inflammation, in this decision-making process, but it can be inferred that they are more concerned regarding behavioral and systemic factors, i.e. cigarette smokers and poorly controlled diabetics. Periodontists are most concerned about patient satisfaction, regardless of tooth position, while they are more concerned with esthetics for anterior teeth and malocclusion for posterior teeth. The top three factors for this decision are (1) bone loss, (2) mobility and (3) esthetics.

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Appendix A

Figures

As I mentioned in our previous correspondence, we are conducting a Delphi survey with the research aim to reach a consensus on criteria for retaining periodontally-involved teeth versus extracting and replacement with a dental implant. The Delphi survey is a systematic method for developing a consensus among experts through use of a questionnaire. This method of structuring a group communication process allows a group of individuals, as a whole, to deal with complex problems [Linstone H., Turoff M (Eds). "The Delphi Method: Techniques and Application". Addison-Wesley, London, 1975].

You were selected for participation as a member of the American Academy of Periodontology due to your knowledge, experience and insight, which are necessary to provide the original ideas required of this study. It provides you the opportunity to interact with other members of the periodontal community in defining criteria for implant placement.

This Delphi study involves two rounds of questionnaires that will take five minutes of your time each. There is no risk of a breach of confidentiality. Your name will not be linked to your questionnaire and answers in any other publications.

Participation is voluntary. If you decide not to participate, there will be no penalty or loss of benefits to which you are otherwise entitled. You may also decide to stop participating at any time, without any penalty or loss of benefits to which you are otherwise entitled.

If you have any additional questions concerning this research or your participation in it, please feel free to contact Dr. Ross Gordon at 614-292-0371, the research supervisor – Dr. Angelo Mariotti at 614-292-0371 or Ms. Sandra Meadows in the Office of Responsible Research Practices at 1-800-678-6251 at any time.

We would like to thank you in advance for your participation.

Best regards,

Ross Gordon, DDS
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Angelo Mariotti, DDS, PhD
Chair, Department of Periodontology
The Ohio State University

Figure 1. Initial letter sent to potential Delphi participants.

1

Survey Instructions

Dear Panelist,

Thank you very much for taking time to complete this survey.

1. Please complete the survey in its entirety.

*** **Note**: We ask that you consider **Mobility & Bone Loss** simultaneously in Question 1 ***

2. Return all five pages of the completed survey in the provided return envelope.

Definition of Indices

Furcation
(Glickman 1953)

Grade I = incipient bone loss
Grade II = partial bone loss (cul-de-sac)
Grade III = total bone loss (through-and-through)

Mobility
(Miller 1985)

Class 1 = horizontal movement of tooth 0.2-1 mm
Class 2 = horizontal movement of tooth > 1 mm
Class 3 = vertical movement of tooth

Plaque Index (PI)
(Silness and Löe 1964)

0 = absence of plaque
1 = plaque film disclosed with probing along margin
2 = visible plaque
3 = abundant plaque

Gingival Index (GI)
(Löe & Silness 1967)

0 = absence of inflammation
1 = slight inflammation
2 = visible inflammation, bleeding-on-probing (BOP)
3 = sever inflammation, spontaneous bleeding

Figure 2. Instructions for round one of the Delphi survey.

2

1) What would you consider the **MINIMAL** necessary clinical findings to extract a tooth and replace it with an implant?

		Mark " X " on value ONCE PER ROW										
		Percent Bone Loss (%)										
Mobility & Bone loss	No Mobility	0	10	20	30	40	50	60	70	80	90	100
	Grade 1 (Miller)	0	10	20	30	40	50	60	70	80	90	100
	Grade 2 (Miller)	0	10	20	30	40	50	60	70	80	90	100
	Grade 3 (Miller)	0	10	20	30	40	50	60	70	80	90	100
Probing depth	(mm)	1	2	3	4	5	6	7	8	9	≥10	
Furcation	Class (Glickman)	1				2				3		

2) Which of the following clinical findings would **PREVENT** you from extracting a tooth and replacing it with an implant? Mark "X"on one value for each category

Plaque	PI (Silness & Loe)	Not a factor	1		2		3
Inflammation	GI (Loe & Silness)	Not a factor	1		2		3
Smoking	Cigarettes per day	Not a factor		<10		≥10	
Diabetes	HbA1C (%)	Not a factor	≤6	7	8	9	≥10

Figure 3. Questions 1 and 2 for round one of the Delphi survey.

3

3a) How concerned are you about the following factors when planning to extract and replace an **ANTERIOR** tooth with an implant?

	Mark "/" on the line		
Requires root canal treatment	Not concerned	_____	Extremely concerned
Root canal therapy requiring retreatment	Not concerned	_____	Extremely concerned
Malocclusion or parafunction	Not concerned	_____	Extremely concerned
Esthetics	Not concerned	_____	Extremely concerned
Pain	Not concerned	_____	Extremely concerned
Patient satisfaction	Not concerned	_____	Extremely Concerned
Cost to patient	Not concerned	_____	Extremely Concerned

Figure 4. Question 3a for round one of the Delphi survey.

4

3b) How concerned are you about the following factors when planning to extract and replace a **POSTERIOR** tooth with an implant?

	Mark "/" on the line		
Requires root canal treatment	Not concerned	_____	Extremely concerned
Root canal therapy requiring retreatment	Not concerned	_____	Extremely concerned
Malocclusion or parafunction	Not concerned	_____	Extremely concerned
Esthetics	Not concerned	_____	Extremely concerned
Pain	Not concerned	_____	Extremely concerned
Patient satisfaction	Not concerned	_____	Extremely Concerned
Cost to patient	Not concerned	_____	Extremely Concerned

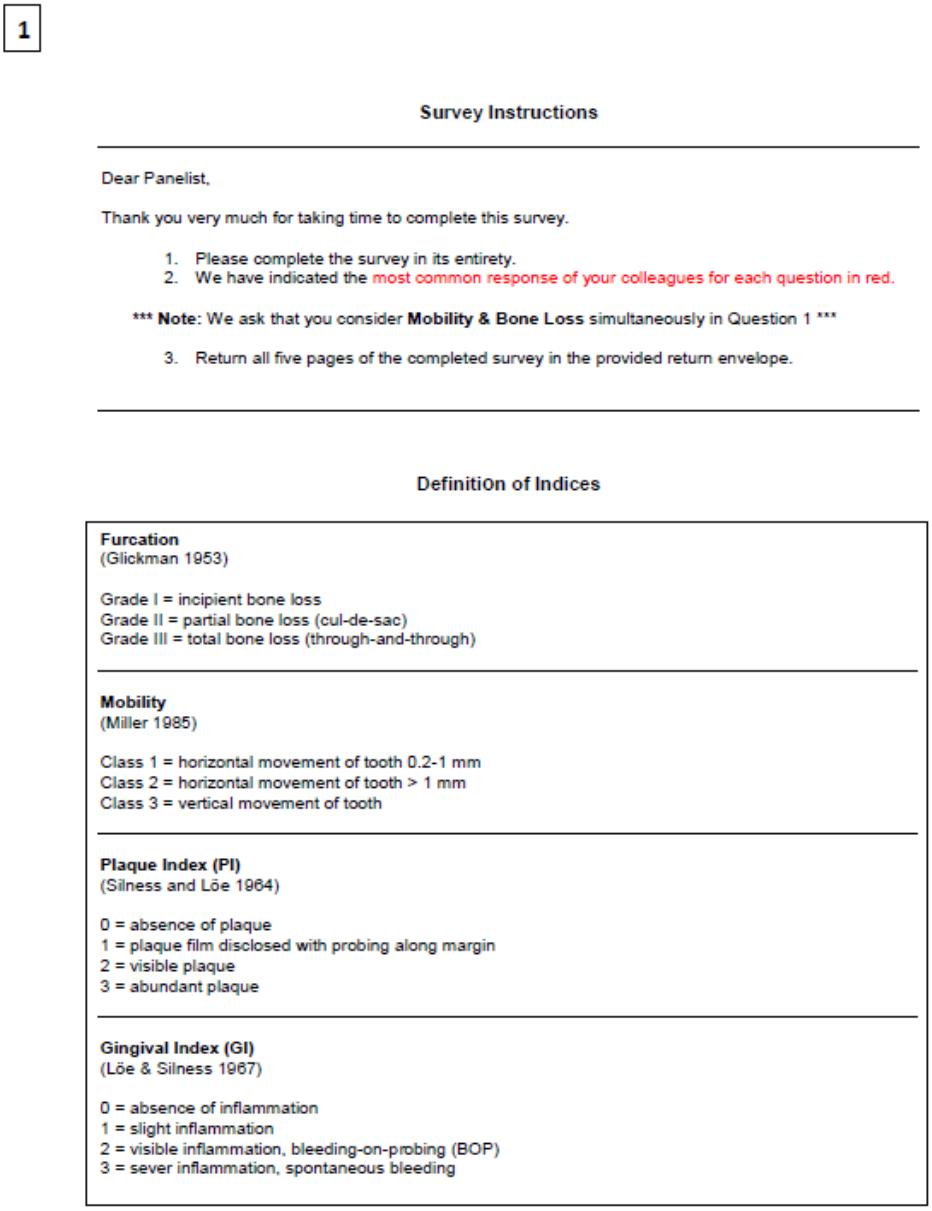
Figure 5. Question 3b for round one of the Delphi survey.

5

4) Please rank your **TOP THREE FACTORS** from **(1) MOST IMPORANT** to **(3) THIRD MOST IMPORTANT** when planning to extract a tooth and replace with an implant:

Mark " 1 ", " 2 ", or " 3 " next to THREE of the factors listed below	
Bone loss	
Cost to patient	
Esthetics	
Furcation involvement	
Gingival inflammation	
Pain	
Patient satisfaction	
Plaque control	
Probing depth	
Malocclusion or parafunction	
Mobility	
Requires RCT	
Previous root canal requiring retreatment	
Smoking status	
Other (please indicate):	

Figure 6. Question 4 for round one of the Delphi survey.



1

Survey Instructions

Dear Panelist,

Thank you very much for taking time to complete this survey.

1. Please complete the survey in its entirety.
2. We have indicated the most common response of your colleagues for each question in red.

*** **Note:** We ask that you consider **Mobility & Bone Loss** simultaneously in Question 1 ***

3. Return all five pages of the completed survey in the provided return envelope.

Definition of Indices

Furcation
(Glickman 1953)

Grade I = incipient bone loss
Grade II = partial bone loss (cul-de-sac)
Grade III = total bone loss (through-and-through)

Mobility
(Miller 1985)

Class 1 = horizontal movement of tooth 0.2-1 mm
Class 2 = horizontal movement of tooth > 1 mm
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Plaque Index (PI)
(Silness and Löe 1964)

0 = absence of plaque
1 = plaque film disclosed with probing along margin
2 = visible plaque
3 = abundant plaque

Gingival Index (GI)
(Löe & Silness 1967)

0 = absence of inflammation
1 = slight inflammation
2 = visible inflammation, bleeding-on-probing (BOP)
3 = sever inflammation, spontaneous bleeding

Figure 7. Instructions for round two of the Delphi survey.

2

1) What would you consider the **MINIMAL** necessary clinical findings to extract a tooth and replace it with an implant?

		Mark " X " on value ONCE PER ROW										
		Percent Bone Loss (%)										
Mobility & Bone loss	No Mobility	0	10	20	30	40	50	60	**70**	80	90	100
	Grade 1 (Miller)	0	10	20	30	40	50	**60**	70	80	90	100
	Grade 2 (Miller)	0	10	20	30	40	50	**60**	70	80	90	100
	Grade 3 (Miller)	0	10	20	30	**40**	50	60	70	80	90	100
Probing depth	(mm)	1	2	3	4	5	6	**7**	8	9	≥10	
Furcation	Class (Glickman)		1				2				**3**	

2) Which of the following clinical findings would **PREVENT** you from extracting a tooth and replacing it with an implant? Mark "X"on one value for each category

Plaque	PI (Silness & Loe)	Not a factor		1	2	3
Inflammation	GI (Loe & Silness)	Not a factor		1	2	3
Smoking	Cigarettes per day	Not a factor		<10		**≥10**
Diabetes	HbA1C (%)	Not a factor	≤6	7	**8**	9 ≥10

Figure 8. Questions 1 and 2 for round two of the Delphi survey.

3

3a) How concerned are you about the following factors when planning to extract and replace an **ANTERIOR** tooth with an implant?

	Mark "/" on the line	
Requires root canal treatment	Not concerned	Extremely concerned
Root canal therapy requiring retreatment	Not concerned	Extremely concerned
Malocclusion or parafunction	Not concerned	Extremely concerned
Esthetics	Not concerned	Extremely concerned
Pain	Not concerned	Extremely concerned
Patient satisfaction	Not concerned	Extremely Concerned
Cost to patient	Not concerned	Extremely Concerned

Figure 9. Question 3a for round two of the Delphi survey.

4

3b) How concerned are you about the following factors when planning to extract and replace a **POSTERIOR** tooth with an implant?

	Mark "/" on the line	
Requires root canal treatment	Not concerned	Extremely concerned
Root canal therapy requiring retreatment	Not concerned	Extremely concerned
Malocclusion or parafunction	Not concerned	Extremely concerned
Esthetics	Not concerned	Extremely concerned
Pain	Not concerned	Extremely concerned
Patient satisfaction	Not concerned	Extremely Concerned
Cost to patient	Not concerned	Extremely Concerned

Figure 10. Question 3b for round two of the Delphi survey.

5

4) Please rank your **TOP THREE FACTORS** from **(1) MOST IMPORANT** to **(3) THIRD MOST IMPORTANT** when planning to extract a tooth and replace with an implant:

Mark " 1 ", " 2 ", or " 3 " next to THREE of the factors listed below		
1	Bone loss	
2	Mobility	
3*	Esthetics	
3*	Furcation involvement	
3*	Patient satisfaction	
3*	Smoking status	
	Cost to patient	
	Gingival inflammation	
	Plaque control	
	Probing depth	
	Malocclusion or parafunction	
	Requires RCT	
	Previous root canal requiring retreatment	
	Pain	

*Indicates tie for third-most important factor from first round

Figure 11. Question 4 for round two of the Delphi survey

Figure 12. Minimum bone loss and tooth mobility necessary for tooth extraction and replacement with an implant. Panel (a): No tooth mobility is present. First round (black bars) and second round (grey bars) responses represent the frequency distribution of 12 panelists concerning the percent of bone loss needed to extract tooth. Panel (b): Grade 1 (Miller, 1965) tooth mobility is present. First round (red bars) and second round (orange bars) responses represent the frequency distribution of 12 panelists concerning the percent of bone loss needed to extract tooth. Panel (c): Grade 2 (Miller, 1965) tooth mobility is present. First round (dark blue bars) and second round (light blue bars) responses represent the frequency distribution of 12 panelists concerning the percent of bone loss needed to extract tooth. Panel (d): Grade 3 (Miller, 1965) tooth mobility is present. First round (green bars) and second round (yellow bars) responses represent the frequency distribution of 12 panelists concerning the percent of bone loss needed to extract tooth.

Figure 12.

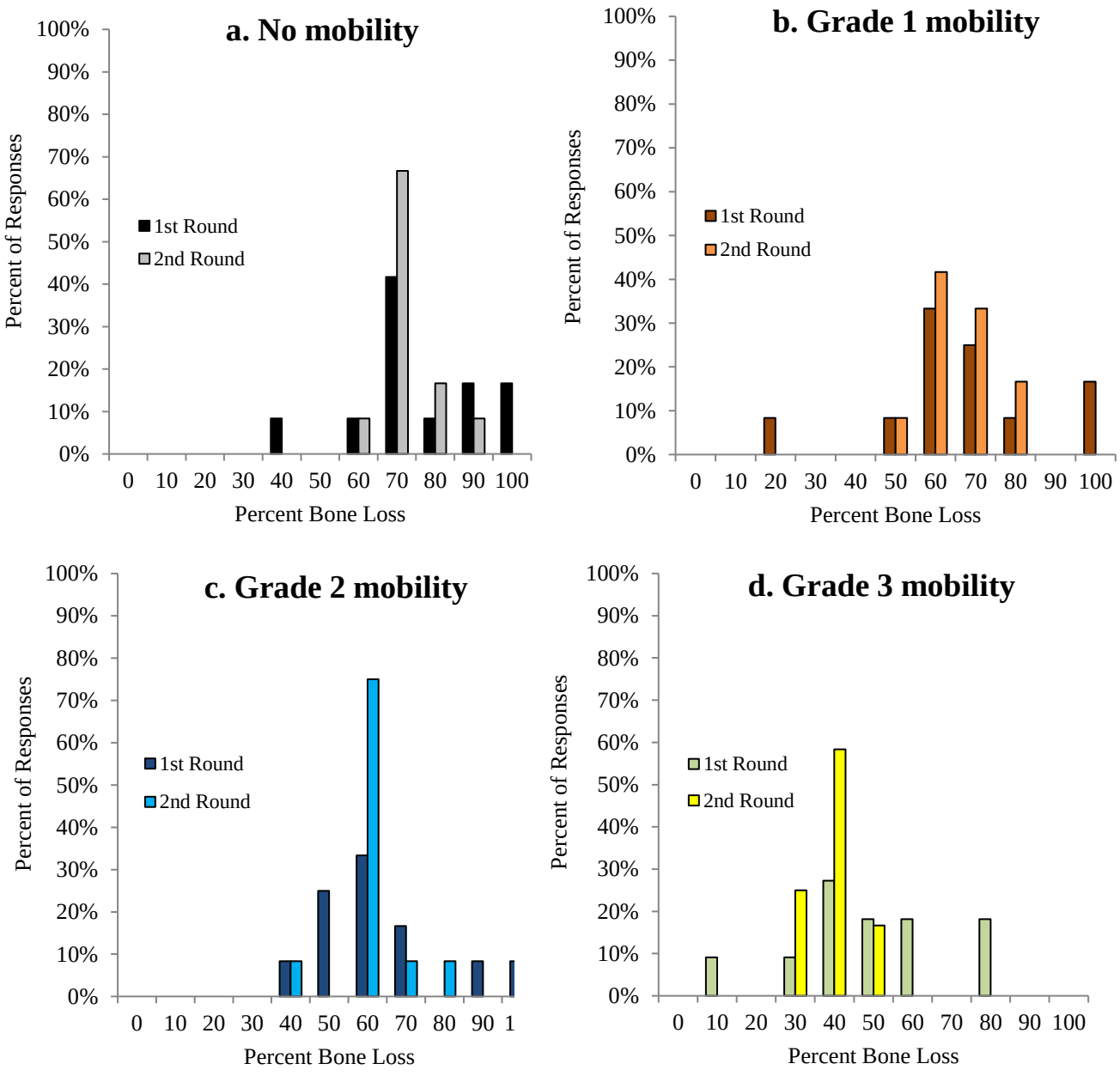
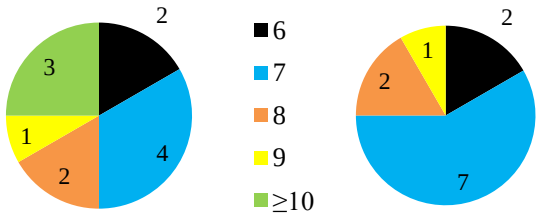

a. No mobility
Percent of Responses
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
1st Round
2nd Round
0 10 20 30 40 50 60 70 80 90 100
Percent Bone Loss
b. Grade 1 mobility
Percent of Responses
1st Round
2nd Round
0 10 20 30 40 50 60 70 80 90 100
Percent Bone Loss
c. Grade 2 mobility
Percent of Responses
1st Round
2nd Round
0 10 20 30 40 50 60 70 80 90 1
Percent Bone Loss
d. Grade 3 mobility
Percent of Responses
1st Round
2nd Round
0 10 20 30 40 50 60 70 80 90 100
Percent Bone Loss

Figure 13. Periodontal and medical criteria affecting the decision for tooth extraction and replacement with an implant. Panel (a): The probing depth (in millimeters) that will trigger tooth extraction and implant placement. Frequency distribution of 12 periodontists for six millimeters (purple), 7 mm (blue), 8 mm (orange) and greater than 10 mm (green) are shown for the first and second rounds. Integers listed around frequency distribution are respondents for each group. Panel (b): The furcation involvement (Glickman, 1954) necessary for tooth extraction and implant placement. Frequency distribution of 12 panelists for Grade 2 (blue) and Grade 3 (orange) furcation involvements are shown for the first and second rounds. Integers listed around frequency distribution are respondents for each group. Panel (c): The minimum plaque accumulation (PlI, Silness and Löe, 1964) that would trigger tooth extraction and implant placement. Frequency distribution of 12 panelists for PlI of 2 (purple), PlI of 3 (orange), or for PlI has no influence on extraction decision (N/A: blue) for the first and second rounds. Integers listed around frequency distribution are respondents for each group. Panel (d): The minimum amount of gingival inflammation (GI, Löe and Silness, 1967) that would trigger tooth extraction and implant placement. Frequency distribution of 12 panelists assessing GI of 2 (purple), GI of 3 (orange) or GI has no influence on extraction decision (N/A: blue) for the first and second rounds. Integers listed around frequency distribution are respondents for each group. Panel (e): The number of cigarettes smoked per day that would trigger tooth extraction and implant placement. Frequency distribution of 12 panelists assessing smoking <10 cigarettes per day (purple), ≥10 cigarettes per day (orange), or cigarette smoking has no influence on extraction decision (N/A: blue) for the first and second rounds. Integers listed around frequency distribution are respondents for each group.

Panel (f): The glycemic index (%HbA1c) that would trigger tooth extraction and implant placement. Frequency distribution of 12 panelists assessing HbA1c of 7% (orange), 8% (blue), 9% (purple), 10% or greater (green), or HbA1c has no influence on extraction decision and implant placement (N/A: yellow) for the first and second rounds. Integers listed around frequency distribution are respondents for each group.

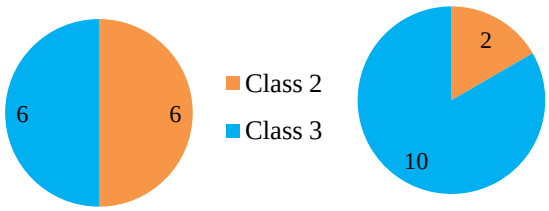
Figure 13.

a. Probing depth



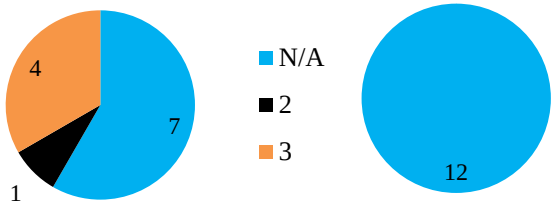
1st Round 2nd Round

b. Furcation involvement



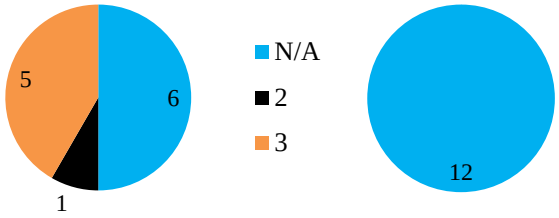
1st Round 2nd Round

c. Plaque accumulation



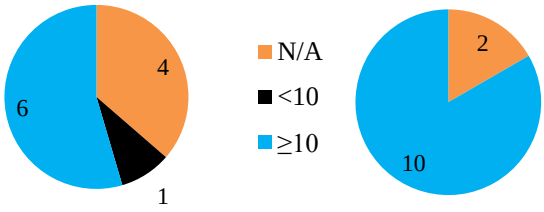
1st Round 2nd Round

d. Gingival inflammation



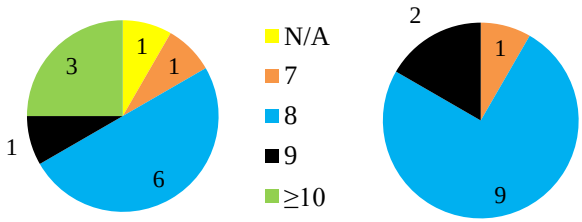
1st Round 2nd Round

e. Smoking status



1st Round 2nd Round

f. Glycemic control



1st Round 2nd Round

Figure 14. Level of concern regarding clinical and patient-centered criteria for extraction of an anterior tooth and replacement with an implant. Panel (a): Tooth requires root canal therapy (RCT). Each of the 12 panelists registered a level of concern from “not concerned” (0%) to “extremely concerned” (100%). Results are expressed as box plots for the first (1) and second (2) rounds. Panel (b): Tooth requires retreatment of root canal therapy (r-RCT). Each of the 12 panelists registered a level of concern from “not concerned” (0%) to “extremely concerned” (100%). Results are expressed as box plots for the first (1) and second (2) rounds. Panel (c): Tooth has malocclusion. Each of the 12 panelists registered a level of concern from “not concerned” (0%) to “extremely concerned” (100%). Results are expressed as box plots for the first (1) and second (2) rounds. Panel (d): Tooth is not esthetic. Each of the 12 panelists registered a level of concern from “not concerned” (0%) to “extremely concerned” (100%). Results are expressed as box plots for the first (1) and second (2) rounds. Panel (e): Tooth causes pain. Each of the 12 panelists registered a level of concern from “not concerned” (0%) to “extremely concerned” (100%). Results are expressed as box plots for the first (1) and second (2) rounds. Panel (f): Patient satisfaction for treatment. Each of the 12 panelists registered a level of concern from “not concerned” (0%) to “extremely concerned” (100%). Results are expressed as box plots for the first (1) and second (2) rounds. Panel (g): Cost of treatment. Each of the 12 panelists registered a level of concern from “not concerned” (0%) to “extremely concerned” (100%). Results are expressed as box plots for the first (1) and second (2) rounds.

Figure 14.

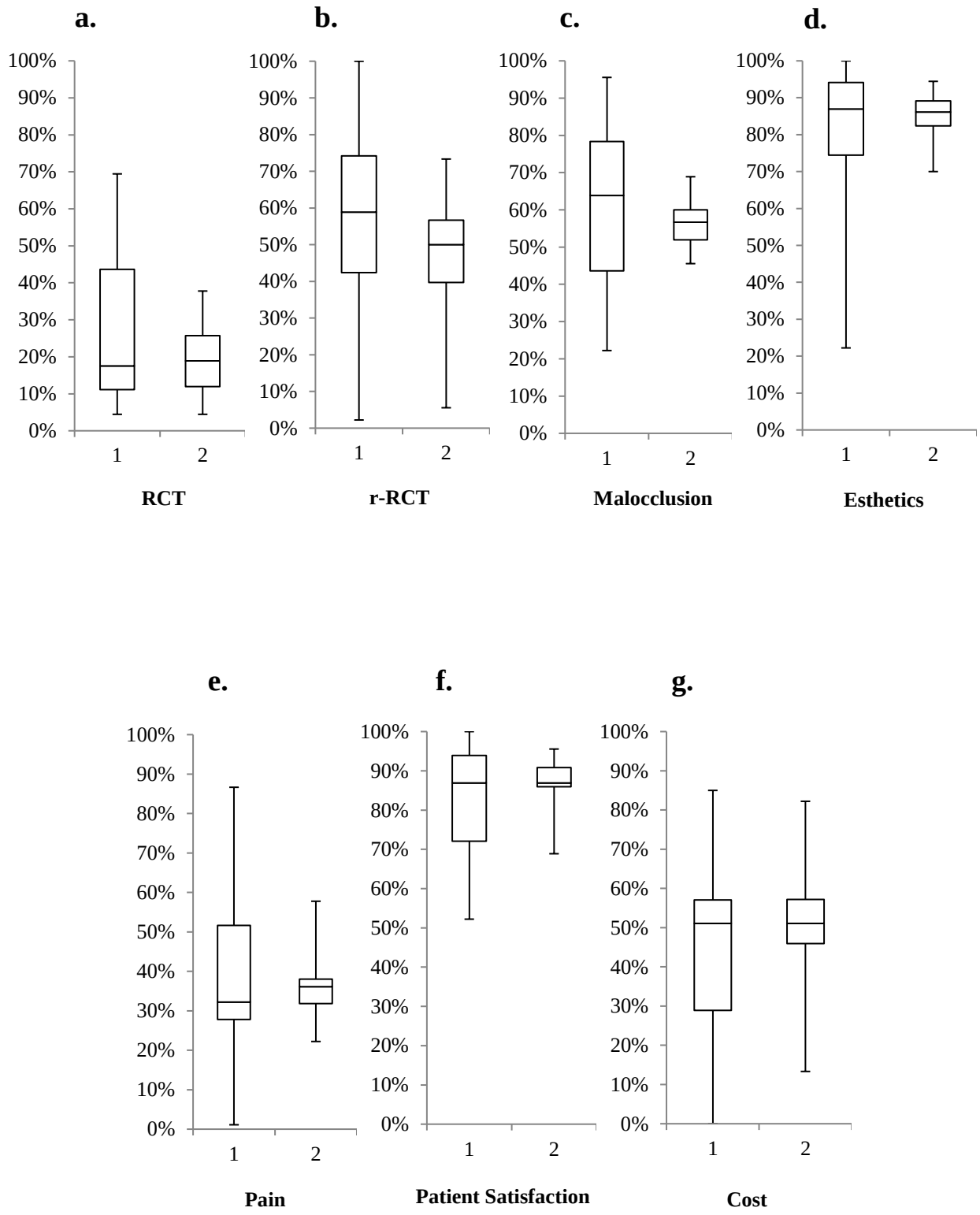

a.
b.
c.
d.
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
1
2
RCT
r-RCT
Malocclusion
Esthetics
e.
f.
g.
Pain
Patient Satisfaction
Cost

Figure 15. Level of concern regarding clinical and patient-centered criteria for extraction of a posterior tooth and replacement with an implant. Panel (a): Tooth requires root canal therapy (RCT). Each of the 12 panelists registered a level of concern from “not concerned” (0%) to “extremely concerned” (100%). Results are expressed as box plots for the first (1) and second (2) rounds. Panel (b): Tooth requires retreatment of root canal therapy (r-RCT). Each of the 12 panelists registered a level of concern from “not concerned” (0%) to “extremely concerned” (100%). Results are expressed as box plots for the first (1) and second (2) rounds. Panel (c): Tooth has malocclusion. Each of the 12 panelists registered a level of concern from “not concerned” (0%) to “extremely concerned” (100%). Results are expressed as box plots for the first (1) and second (2) rounds. Panel (d): Tooth is not esthetic. Each of the 12 panelists registered a level of concern from “not concerned” (0%) to “extremely concerned” (100%). Results are expressed as box plots for the first (1) and second (2) rounds. first (1) and second (2) rounds. Panel (e): Tooth causes pain. Each of the 12 panelists registered a level of concern from “not concerned” (0%) to “extremely concerned” (100%). Results are expressed as box plots for the first (1) and second (2) rounds. Panel (f): Patient satisfaction for treatment. Each of the 12 panelists registered a level of concern from “not concerned” (0%) to “extremely concerned” (100%). Results are expressed as box plots for the first (1) and second (2) rounds.

Figure 15.

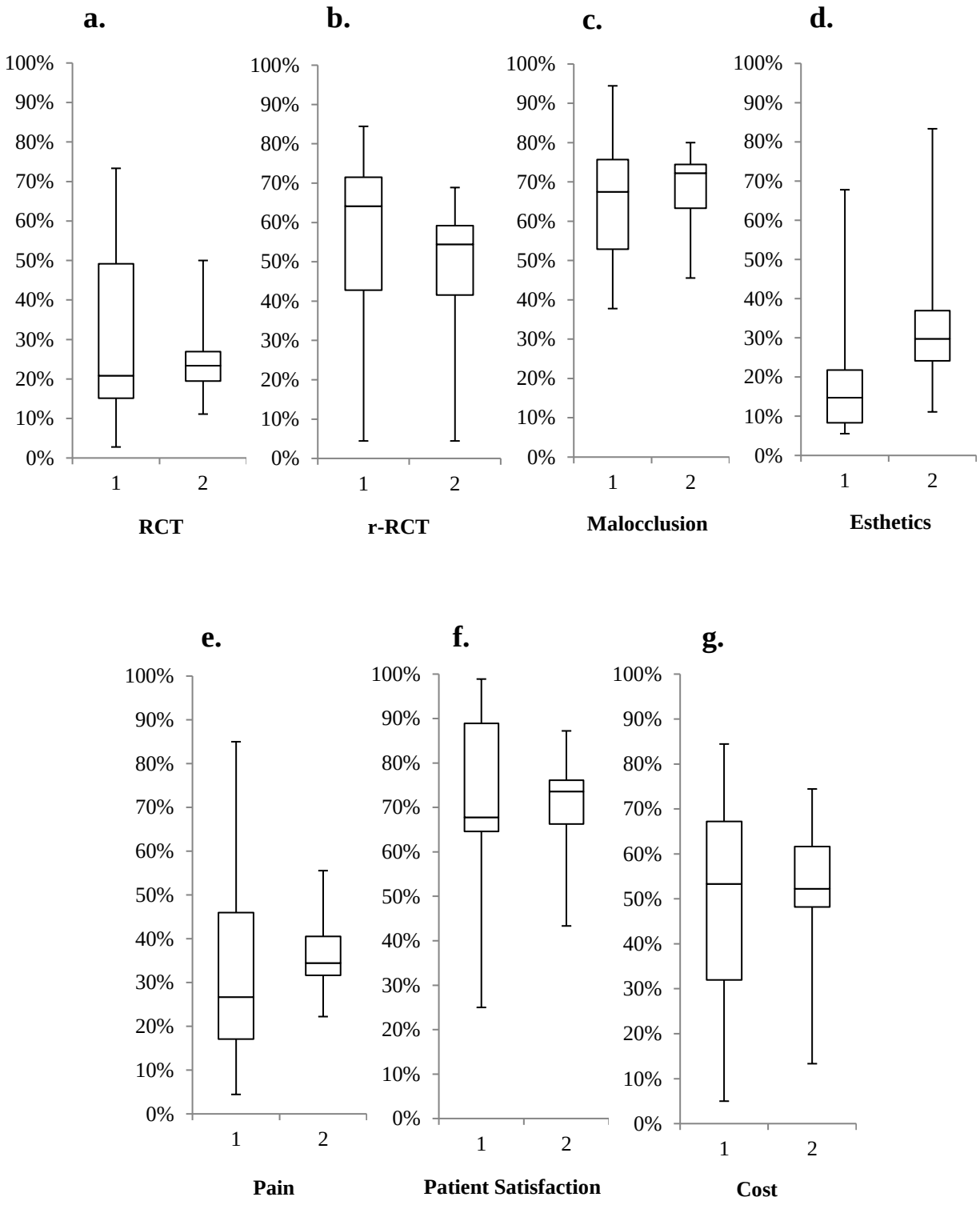
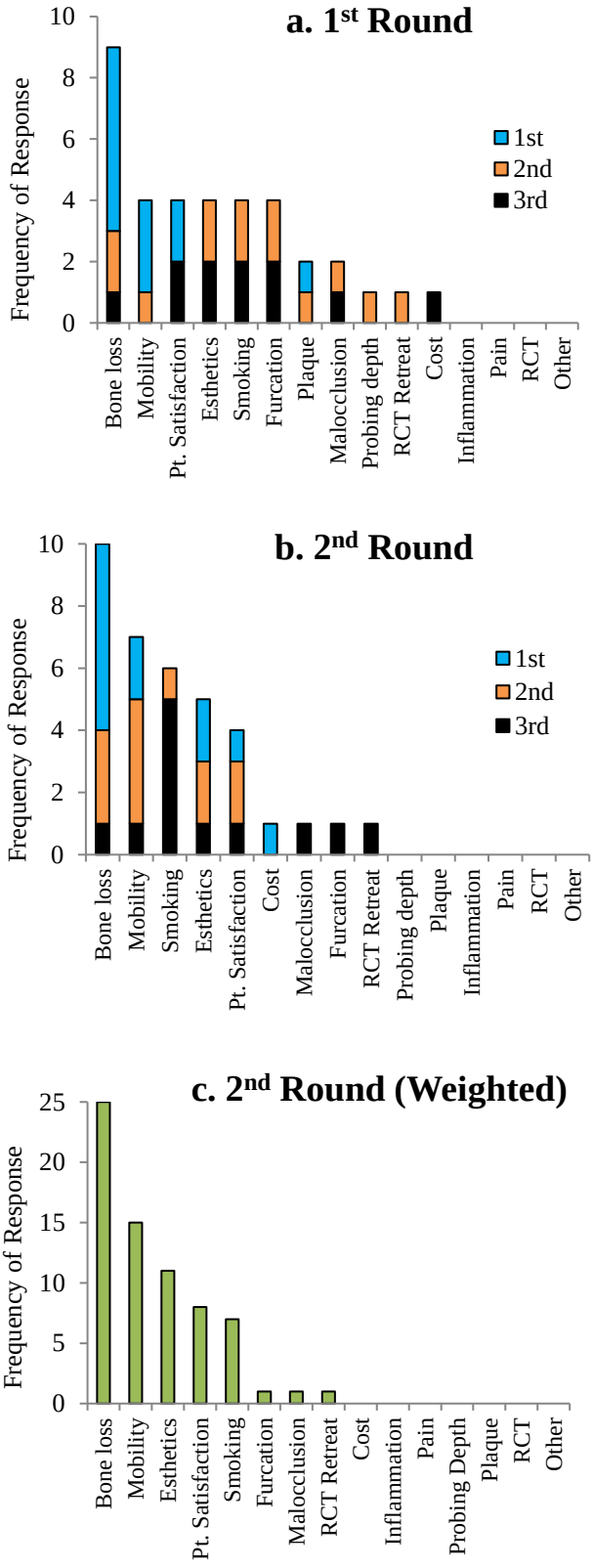

a.
b.
c.
d.
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
1
2
RCT
r-RCT
Malocclusion
Esthetics
e.
f.
g.
Pain
Patient Satisfaction
Cost

Figure 16. Hierarchy of factors for tooth extraction and replacement with an implant. Panel (a): Frequency distribution of most important factor (blue), second most important factor (orange), and third most important factor (purple) for tooth extraction and implant placement for first round of Delphi survey. Panel (b): Frequency distribution of most important factor (blue), second most important factor (orange), and third most important factor (purple) for tooth extraction and implant placement for second round of Delphi survey. Panel (c): Weighted frequency distribution of most important factors (green) for tooth extraction and implant placement for second round of Delphi. Most important factors are weighted by a factor of three, second-most important factors by a factor of two, and third-most important factors by a factor of one.

Figure 16.


a. 1st Round
Frequency of Response
10
8
6
4
2
0
1st
2nd
3rd
Bone loss
Mobility
Pt. Satisfaction
Esthetics
Smoking
Furcation
Plaque
Malocclusion
Probing depth
RCT Retreat
Cost
Inflammation
Pain
RCT
Other
b. 2nd Round
Frequency of Response
10
8
6
4
2
0
1st
2nd
3rd
Bone loss
Mobility
Smoking
Esthetics
Pt. Satisfaction
Cost
Malocclusion
Furcation
RCT Retreat
Probing depth
Plaque
Inflammation
Pain
RCT
Other
c. 2nd Round (Weighted)
Frequency of Response
25
20
15
10
5
0
Bone loss
Mobility
Esthetics
Pt. Satisfaction
Smoking
Furcation
Malocclusion
RCT Retreat
Cost
Inflammation
Pain
Probing Depth
Plaque
RCT
Other