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REVIEW ARTICLE

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Single-rooted extraction socket classification: A systematic review and proposal of a new classification system based on morphologic and patient-related factors

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Abstract

Taxonomy and classification of a disease contributes to facilitating the diagnosis and treatment planning process and simplifies communication between clinicians. The aim of this study was to provide a critical appraisal based on a systematic review of the single-rooted extraction socket (ES) classifications and subsequently, introduce a new classification system combining the cornerstones of the previously proposed systems and based on the latest consensus in implant dentistry. Following the systematic search process in PubMed, EMBASE, and SCOPUS databases 13 ES classifications were detected. The most repeated hard and soft tissue factors in the previous classifications were buccal bone dehiscence, interproximal bone, gingival recession, and soft tissue phenotype. However, there was minimal attention to patient-related factors such as systemic conditions and smoking. Therefore, a new classification system based on the combination of patient-related factors, clinical and radiographical parameters was proposed. This divides an ES into three types. Class I and II sockets are candidates for receiving immediate implant placement and conversely, a class III socket includes a compromised condition that requires multiple-stage reconstruction mostly suitable for standard delayed implant placement with alveolar ridge preservation. Within the limitations of this study, the new classification system not only provides comprehensive inclusion of various crucial parameters in implant placement (such as prediction of future implant position and osteotomy difficulty, etc.) but also, in contrast to the previously introduced systems, is able to classify the ES prior to extraction and also, takes into the account the patient-related factors as the class modifiers following the extraction.

KEYWORDS
classification, dental socket, extraction socket, immediate implants

1 | INTRODUCTION

Tooth extraction is indicated when a tooth has a hopeless prognosis.[1–3] Following the extraction, alveolar ridge resorption is often unavoidable, which may lead to compromised implant placement.[4] Depending on the hard and soft tissue conditions of the extraction socket (ES), various treatment approaches such as alveolar ridge preservation (ARP) or immediate implant placement (IIP) have been attempted.[5] The buccal plate thickness, buccal bone morphology, overlying soft tissue, and the pathologic condition of the socket are among the most important factors affecting the treatment decision-making and prognosis.[6,7]

Classification of a disease is crucial as it helps clinicians to identify the pathophysiology, symptomatology, diagnosis, and treatment approach. Likewise, it could be beneficial for the patients if an ES decision tree can be developed based upon the above available information. Generally, classification serves as a valuable tool for better communication between clinicians and patients and among researchers.[8] Ideally, a classification system should be user-friendly, precise and comprehensive without any overlaps between the disease entities, and based on the latest knowledge of pathophysiology and biology.[9]

Several single-rooted ES classification systems are available today, most of these classifications aim to predict the IIP according to the remaining buccal bone and/or overlying soft tissue components. However, the presence of many ES classification systems may create unnecessary confusion among involved parties. Moreover, there is lack of consensus with regards to which ES classification should be used. Each of the proposed systems possesses strengths as well as limitations. For instance, one may include a thorough evaluation of the hard tissue without considering the soft tissue elements whereas another one may only focus on soft tissue.[10] Therefore, the aim of this article was to provide a critical appraisal of current existing ES classifications within the framework of a systematic review and propose a new single-rooted ES classification that takes into consideration all important factors based on the latest evidence and consensus in implant dentistry.

2 | MATERIALS AND METHODS

2.1 | Protocol and registration

The analysis and interpretation methodology of this study were defined within the framework of a protocol and registered prior to initiation in PROSPERO portal (CRD42022345141). Moreover, the protocol and the search strategy were created based on the Preferred Reporting Items for Systematic Review and Meta-analysis (PRISMA) statement (Appendix S1).

2.2 | Problem, intervention, comparison, and outcome (PICO) statement

Problem (P): Lack of consensus regarding the single-rooted ES classification.

Intervention (I): Evaluation of available ES classification systems.

Comparison (C): Comparison of the included variables and factors into each ES classification.

Outcome (O): Proposal of a new single-rooted ES classification system to ease the decision-making process.

2.3 | Focused question

Based on the stated PICO design, the focused question for this study was proposed as follows:

What are the currently available ES classification systems for single-rooted sockets, the factors concerning ES that are considered and the suggested treatment approaches?

2.4 | Systematic search strategy

A systematic search approach was performed by two authors (Hamoun Sabri, Shayan Barootchi) in the electronic databases of: PubMed (MEDLINE), Embase, and Scopus, aiming to identify all proposed ES classification systems until January 1, 2022. The main keywords were: "extraction socket" OR "tooth socket" AND "Classification." The complete performed searching process and keywords are available as the Appendix 2.

The inclusion criteria were reserved to the following articles:

1. Presenting a new single-rooted ES classification system compared to the previously introduced ones.

On the contrary, the exclusion criteria were as follows:

1. Articles in which the authors implemented one of the previously published systems.
2. Studies with focus on a different topic besides ES classification.
3. Molar (multi-rooted) ES classifications.
4. Theses, abstracts, letters to the editors and editorials.

Moreover, no limitations were applied in terms of the language and date of the publication.

The search results were imported into EndNote (version X9) and deduplicated based on title, and additionally, the automatically identified duplicates were double-checked manually. Two reviewers (Hamoun Sabri, Shayan Barootchi) screened the results independently against the eligibility criteria using Review manager (REVMAN) software (version 5.3.5). The full-text reading of the selected articles was performed searching for the other classification systems (if had not been included) and those detected from the screening of the reference list of the included articles were also added. In case of any discrepancies between the two reviewers, this resolved by referring to the senior reviewer (Hom-Lay Wang). The inter-reviewer reliability in the screening and inclusion process were assessed with Cohen's k test. The included articles were thoroughly reviewed and analyzed.

2.5 | Types of included studies

This systematic review contained prospective, retrospective, cohort, case–control, review studies without any language and date limitation.

2.6 | Data extraction

Based on the aim of the study, the following data were extracted independently from the included ES classifications: Study design, date of publication, proposed ES types and description in each classification, parameters based on which the ES classification was performed and suggested treatment approach and considerations for each type of socket.

2.7 | Quality assessment of the included studies

The full texts of the included ES classifications were determined with regards to their methodological quality and validity. This was performed based on the COnsensus-based Standards for the selection of health Measurements (COSMIN) checklist.[11,12] Fundamentally, this checklist was applied to thoroughly investigate the methodological quality of each classification.[13,14] This checklist evaluates three measurement property of reliability, validity, and responsiveness. Based on these three components, 10 Boxes have been defined on the COSMIN platform (patient reported outcomes, internal consistency, reliability, measurement error, content validity, structural validity, hypothesis testing, cross-cultural validity, criterion validity, and responsiveness) 8 of which were eligible for this study (patient reported outcomes and cross-cultural validity were excluded). Two reviewers performed the quality assessment (Hamoun Sabri, Shayan Barootchi) and in case of disagreement the third investigator (Hom-Lay Wang) confirmed the decision.

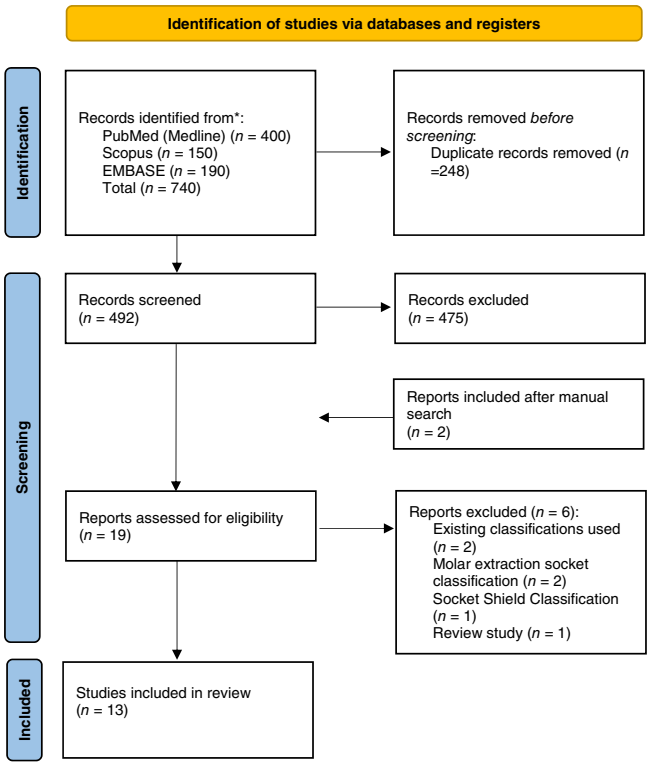

FIGURE 1 The PRISMA chart of the identification, screening, and selection process of the present systematic review. ES, extraction socket; PRISMA, Preferred Reporting Items for Systematic Review and Meta-analysis

3 | RESULTS

3.1 | Search results and study selection

The literature search process, based on the PRISMA guidelines is shown in Figure 1. This consisted of two stages. Firstly, following the primary search, 740 articles were identified. Following removal of duplicates, 492 records remained for screening by titles and abstracts. After thorough evaluation of the titles and abstracts 17 articles were selected. As the second stage, after the manual screening of the reference list of the articles, two additional ES classifications were also detected and included to the study. Following the full-text assessment of these studies and based on predetermined inclusion criteria, 13 articles were included in the qualitative analysis. The reasons for exclusion of the six records are provided in Table 1. The inter-reviewer reliability in the screening and inclusion process, as assessed with Cohen's k, corresponded to 0.91 and 0.88 for assessment of titles and abstracts and full-text evaluation respectively.

TABLE 1 Excluded studies and the reasons for exclusion

Authors	Type of study	Reason for exclusion
Kumar and Kher[51]	Case report and review	Socket shield classification
Juodzbalys et al.[39]	Systematic review	Review of socket augmentation and ARP
Al-Shabeeb et al.[52]	Pilot animal study	An existing ES classification was implied
Juodzbalys and Wang[53]	Pilot clinical study	An existing ES classification was implied
Smith and Tarnow[54]	Technical note	Molar extraction socket classification
Bleyan and Gaspar[55]	Retrospective	Molar extraction socket classification

Abbreviations: ARP, alveolar ridge preservation; ES, extraction socket.

3.2 | Findings from the COSMIN quality assessment of the classifications

Using the COSMIN checklist, the quality of the ES classification systems included in this study was evaluated (Table 2). Out of 13 classifications, none of them met the criteria for adequate internal consistency and responsiveness. 10 of the included classifications lacked "adequate" or "very good" properties in any of the 8 evaluated entity.[10,15–23] Overall, the classification system by Juodzbalys et al.,[6] had "adequate" reliability and testing "measurement error". Moreover, although the classifications by Chang and Cheng[4] and Kim et al.,[24] yielded "adequate" hypothesis testing and structural validity respectively, all the other tested parameters were either "inadequate" or "doubtful." Overall, the results of this quality assessment revealed a strong deficiency in terms of the validity and reliability of the existing classification systems.

TABLE 2 COSMIN[a] checklist for the quality assessment of the existing extraction socket classification systems

		Reliability			Validity				
Classification system	Components	Internal consistency	Reliability	Measurement error	Content validity	Structural validity	Hypotheses testing	Criterion validity	Responsiveness Responsiveness
Salama and Salama, 1993[15]	Apical residual bone Defect walls Dehiscence	Inadequate	Inadequate	N/A	N/A	Inadequate	Doubtful	N/A	Inadequate
Tinti and Parma-Benfenatti, 2003[19]	Bone housing around the placed implant	Inadequate	Inadequate	Inadequate	N/A	Inadequate	Inadequate	N/A	Inadequate
Caplanis et al., 2005[23]	Tissue phenotype Number of affected walls Ht loss Past medical and dental history Systemic risk factors	Inadequate	Inadequate	Inadequate	Inadequate	Doubtful	Inadequate	Inadequate	Inadequate
Elian et al., 2007[16]	Buccal HT Buccal ST	Inadequate	Inadequate	Inadequate	Inadequate	Inadequate	Inadequate	Inadequate	Inadequate
Juodzbalys et al., 2008[6]	Alveolar process height Apical residual bone Labial plate thickness and position Pathology St phenotype	Doubtful	Adequate	Adequate	Doubtful	Doubtful	Doubtful	Doubtful	Inadequate
Al-Hezaimi et al., 2011[10]	Blood supply Adjacent teeth	Inadequate	Inadequate	Inadequate	Inadequate	Inadequate	Inadequate	Inadequate	Inadequate
Iyer et al., 2014[20]	Buccal plate thickness Number of affected walls	Inadequate	Inadequate	Inadequate	Inadequate	Inadequate	Inadequate	Inadequate	Inadequate
Chu et al., 2015[22]	Residual buccal bone (intact ST in all types)	Inadequate	Inadequate	Inadequate	Inadequate	Inadequate	Inadequate	Inadequate	Inadequate
El Chaar et al., 2016[17]	Residual buccal bone Interproximal bone Apical residual bone ST phenotype	Inadequate	Inadequate	Inadequate	Inadequate	Inadequate	Inadequate	Inadequate	Inadequate
Al-Yafi et al., 2019[21]	Dehiscence and fenestration Buccal plate thickness Interproximal bone ST phenotype Recession Esthetic concern	Inadequate	Inadequate	Inadequate	Inadequate	Inadequate	Inadequate	Inadequate	Inadequate
Chang and Cheng, 2021[4]	HT destruction ST destruction Infection Systemic disease	Inadequate	Inadequate	Doubtful	Doubtful	Inadequate	Adequate	Inadequate	Inadequate

(Continues)

TABLE 2 (Continued)

Classification system	Components	Reliability			Validity				Responsiveness Responsiveness
		Internal consistency	Reliability	Measurement error	Content validity	Structural validity	Hypotheses testing	Criterion validity	
Kim et al., 2021[24]	Buccal bone loss Palatal bone loss Remaining HT walls ST Destruction Etiology of extraction	Inadequate	Inadequate	Inadequate	Doubtful	Adequate	Inadequate	Doubtful	Doubtful
Cardaropoli et al., 2021[18]	ST level Buccal Plate resorption Local bone anatomy	Inadequate	Inadequate	Inadequate	Inadequate	Inadequate	Inadequate	Inadequate	Inadequate

Abbreviations: HT, hard tissue; N/A, not available; ST, soft tissue.
[a]Patient reported outcome results and cross-cultural validity were not applicable to this study.

3.3 | Description of the included studies

A summary of all ES classifications including the factors considered, treatment protocols for each subtype is provided in Table 3.

3.4 | Brief history of ES classifications

The very first attempt to introduce a classification system for single-rooted ESs was proposed by Salama and Salama[15] in 1993. This was within the framework of the regenerative potential based on the guidelines of infrabony periodontal defects, local topography and specifically, the remaining buccal plate. Later on, in 2003, another classification was introduced by Tinti and Parma-Benfenatti.[19] This was based on the remaining bony housing around the future implants and its regenerative potential. Caplanis et al.;[23] however, were the first group to add the soft tissue parameters to the classification system in addition to the hard tissue components.

Later on, Elian et al.,[16] introduced a simplified classification as well as a non-invasive approach for the management of ESs where the soft tissue is present, but the buccal plate is compromised. A sub-classification for this system was introduced in 2015 by Chu et al.,[22] in which they aimed to provide a more detailed description for the type 2 defects. Similar to Elian's classification, Juodzbalys et al.,[6] aimed to classify the ESs based on the quantitative and qualitative evaluations of both soft and hard tissue adjacent to the socket.[6] The only animal study that was included to this review was conducted by Al-Hezaimi et al., in 2011.[10] They concluded that a compromised interdental blood supply, and consequently, the interdental remaining bone contributes to the bone resorption in ES and proposed their classification based on the presence of adjacent teeth and the situation of interdental bone. Another ES classification was introduced by El Chaar et al.,[17] group, mainly based on the bone topography of the socket.

More recently proposed classifications consist of Iyer et al.,[20] in 2019, which was solely based on the hard tissue components, and Chang and Cheng,[4] Kim et al.,[24] and Cardaropoli et al.,[18] classifications all published in 2021. The Chang and Cheng's[4] system is a modification for Elian's classification, which is based on the amount of tissue destruction in all four walls of ESs. The classification by Kim et al.,[24] refers to the pathologically affected, single-rooted ESs. Fundamentally, this was done based on the hard and soft tissue condition of ESs following tooth loss due to periodontal and/or endodontic infection. Similarly, identical variables were also taken into consideration by Cardaropoli's classification.[18]

3.5 | Included factors in existing classification systems

After a thorough evaluation of the detected ES classification systems, the proposed parameters that are taken into account to classify sockets for all the classifications were evaluated. Generally, the

TABLE 3 The characteristics of the included single-rooted extraction socket classification systems

Classification	Study design	Soft tissue parameters	Hard tissue parameters	Patient related factors	Subtypes	Treatment approach	Considerations
Salama and Salama, 1993[15]	Case series	None	Residual bone around apex Defect walls Dehiscence	None	T1	IIP/Adjunctive treatments if compromised or severe case	–
					T2	DIP + ARP or forced eruption	–
					T3	DIP + regeneration with DFDB allografts + tetracycline covered by a membrane	–
Tinti and Parma-Benfenatti, 2003[19]	Case series	None	Bone housing around the placed implant	None	C1	N/A	–
					C2	N/A	–
Caplanis et al., 2005[23]	Review	Tissue phenotype Soft tissue predictability	Number of affected walls HT Loss	Past medical and dental history Detection of systemic risk factors	EDS-1	IIP	–
					EDS-2	ARP + IIP or ARP + DIP	–
					EDS-3	ARP + DIP	–
					EDS-4	ARP + Site development + DIP (three stage)	–
Elian et al., 2007[16]	Case series	Remaining buccal ST	Remaining Buccal HT	None	TI	IIP/DIP	The easiest and most predictable
					TII	Staged approach with HT and with or without ST augmentation	Risk of misdiagnosing as type I/difficult to diagnose
					TIII	Staged approach with HT with or without ST augmentation	Require experience, dexterity, and time
Juodzbalys et al., 2008[6]	Case series	Tissue phenotype ST quality (color, consistency, contour)	Alveolar process height Residual bone around apex Labial plate thickness and position Pathology	None	TI	IIP	Optimal esthetic outcomes expected
					TII	IIP or DIP with ST or HT augmentation	–
					TIII	DIP after ST or HT augmentation or orthodontic forced eruption	–
Al-Hezaimi et al., 2011[10]	Animal study	Blood supply to the area	Presence of adjacent teeth	None	CI	N/A	–
					CII	N/A	–
					CIII	N/A	–
Iyer et al., 2014[20]	Review and case series	None	Buccal plate thickness Number of affected walls	None	CI	IIP without ARP/ARP + DIP	–
					CII	IIP + graft/DIP + graft or ARP	
					CIII	Particulate graft + IIP if primary stability achievable	
					CIV	Socket walls regeneration + DIP	
					CV	Augmentation with autogenic or allogenic grafts + DIP	
					CVI	Major interventions (e.g., distraction osteogenesis and etc.) + DIP	
Chu et al., 2015[22]	Case series	Intact Labial ST in all types	Residual buccal bone	None	T2A	IIP + GBR (caution on T2C sockets)	–
					T2B		–
					T2C		–

(Continues)

TABLE 3 (Continued)

Classification	Study design	Soft tissue parameters	Hard tissue parameters	Patient related factors	Subtypes	Treatment approach	Considerations
El Chaar et al., 2016[17]	Case series	ST phenotype	Apical topography Buccal plate loss% Interproximal bone	None	GI	IIP with without provisionalization and bone graft	–
					GII	Thin phenotype: DIP + ARP Thick phenotype: IIP without temporization	–
					GIII	ARP or forced eruption	In case of compromised apical topography→ DIP + GBR
Al-Yafi et al., 2019[21]	Review	Tissue phenotype Recession	Dehiscence and fenestration Buccal plate thickness Interproximal bone height	Esthetic concern	CIA	IIP/2 Stage	3 Stage approach: ARP + Site development + implant placement
					CIB	IIP/2 Stage	
					CIIA	IIP with grafting/2 Stage	
					CIIB	2 Stage/3 Stage	
					CIIIA	IIP with grafting/2 Stage	
					CIIIB	2 Stage/3 Stage	
					CIVA	IIP with grafting/2 stage	
					CIVB	3 Stage	
Chang and Cheng, 2021[4]	Retrospective	ST destruction	HT destruction	Systemic disease Infection	CI	Varies based on the patient related factors: Natural healing to ridge augmentation	IIP can be performed if primary stability is achievable
					CII		
					CIII		
					CIV		
Kim et al., 2021[24]	Cohort	Buccal ST level	Number of remaining walls Buccal and palatal bone loss	Etiology of the tooth loss	TI	IIP	If no infection or thin buccal plate is present
					TII	IIP + GBR or DIP	Risk of compromised esthetics in IIP DIP preferred in extensive destruction
					TIII	ARP + CTG or FGG	–
					TIV	Ridge augmentation	Augmentation beyond the present envelope of bone
					TV	Extensive ridge augmentation (complementary bone augmentation after healing)	–
Cardaropoli et al., 2021[18]	Case series	ST level	Buccal Plate resorption Local bone anatomy	None	CI	IIP/ARP + DIP	–
					CII	Ridge augmentation + DIP/ DIP + simultaneous bone augmentation	
					CIII	Ridge augmentation W/WO ST augmentation + DIP/DIP with simultaneous bone augmentation	
					CIV	Ridge augmentation W/WO ST augmentation + DIP/Delayed bone augmentation + DIP/	

Abbreviations: ARP, alveolar ridge preservation; C, class; CTG, connective tissue graft; DFDB, demineralized freeze-derived bone; DIP, delayed implant placement; EDS, extraction defect sounding; ES, extraction socket; FGG, free gingival graft; G, grade; GBR, guided bone regeneration; HT, hard tissue; IIP, immediate implant placement, ST, soft tissue; T, type.

parameters which have been used to evaluate the socket prior to the classification can be divided into three groups: hard tissue parameters, soft tissue parameters and patient related factors. Figure 2 shows the pie chart of the included factors to all the selected ES classifications.

3.5.1 | Hard tissue parameters

Remaining buccal bone dimensions

The buccal bone dimensions, including thickness, buccal bone loss such as dehiscence, are taken into account in almost all ES classifications. Only two studies introduced the hard tissue dehiscence as a main factor to consider.[15,21] However, this consisted of solely qualitative evaluation (presence or absence).

The extent of buccal bone loss was considered as a parameter to classify the socket in nine studies.[4,6,16–18,21–24] According to the reviewed studies, the amount of acceptable buccal bone loss allowing for IIP is up to 2 mm or 20%–25% of resorption.[6,17,18,23] Moreover, one study also added the amount of bone loss on the palatal aspect in addition to buccal.[24] The thickness of the buccal plate is also included in four systems.[6,20,21,23] All classification systems considered at least 2 mm of buccal bone thickness as an acceptable parameter for IIP.

Defect walls

This parameter has taken into account in four systems.[15,23,20,24] Overall, it can be stated that based on the included classifications, the regenerative potential as well as the vascularity of the socket decreases in 3- or less-wall defects compared to a 4-wall intact bony structure and the prognosis of an IIP in 4-wall defects, provided that the other parameters are also in optimum levels, can be considered as "good."[17,20,21]

Apical topography

Three of the selected ES classification systems considered the apical topography as a main factor to classify defects.[6,15,19] Moreover, the rationale to bear in mind is the amount of remaining bone in the apical region to be engaged with the implant. For instance, the minimum amount of remaining bone is around 3 to 4 mm, to be in contact with the implant.[6,17]

Future peri-implant hard tissue

The foreseeable amount of bone housing around the future implants were considered by Tinti and Parma-Benfenati[19] for the single-rooted socket classification. This refers to the importance of an intact envelope of bone for clot stability.

Finally, El Chaar et al.,[17] and Al-Yafi et al.,[21] added the interproximal bone parameter to the previous criteria, as the level of

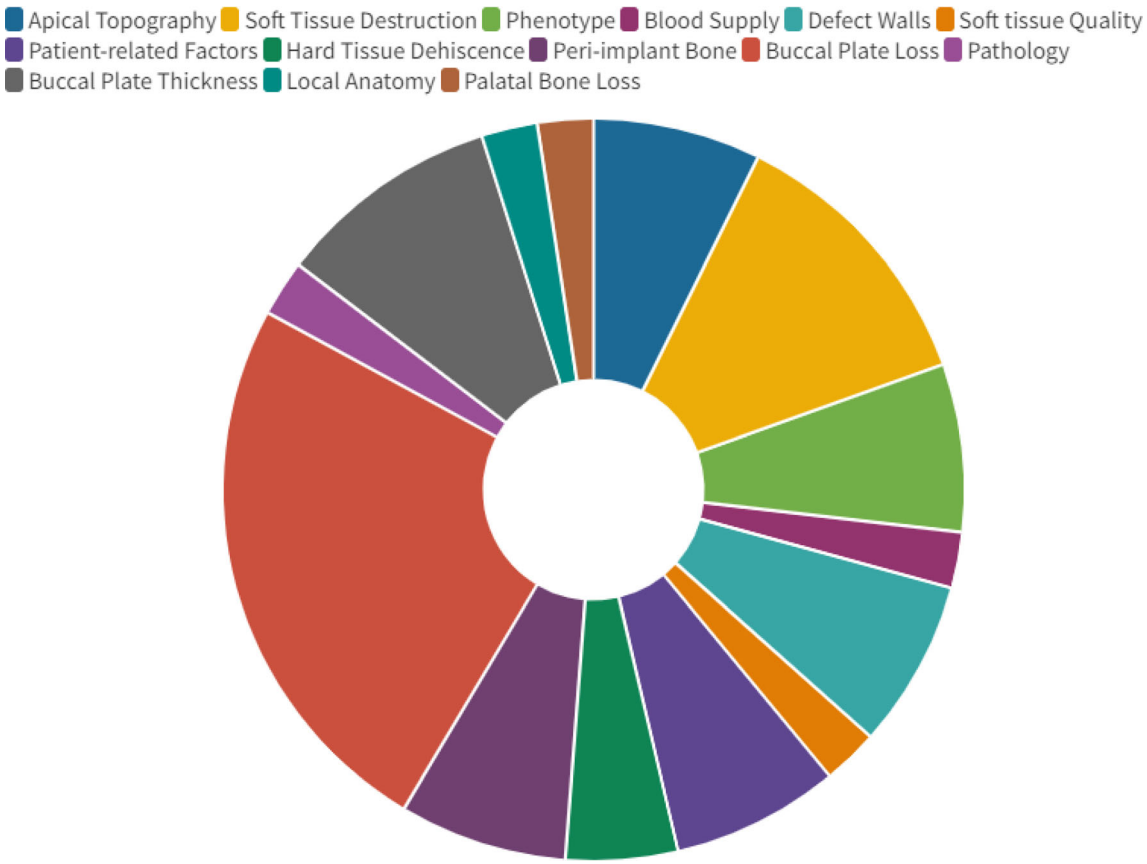

FIGURE 2 The pie chart of all parameters that are taken into account by the previous classification systems included to this study

TABLE 4 The new extraction socket classification. Class I: refers to a socket with ideal condition and able to receive IIP. The etiology for extraction is not periodontitis-related and mostly includes endodontic-related origins and excessive caries or fracture. The amount of gingival recession does not exceed 3 mm. the soft tissue phenotype is thick. In the radiographic images, at least 2 mm of buccal bone thickness without dehiscence, interproximal bone loss and apical pathology can be seen. The root position is ideal for IIP planning. Class II: Whenever the ES includes at least one of the proposed criteria in this class, it will be considered as a Class II socket. This consists of a mildly affected socket. A thin phenotype can be detected. Radiographic parameters include less than 2 mm of buccal bone thickness and less than 50% dehiscence with or without interproximal bone loss and/or apical lesion. The root position is adjacent to the palatal plate. Mild periodontal or endo-perio origin can be a feature of class II sockets. Class III: The etiology of a class III socket can be severe perio or endo-perio lesions. The gingiva has more than 3 mm of recession also severe loss of buccal plate in terms of dehiscence puts a socket into class III. The root position in unfavorable with only 2/3 of the root engaging the buccal and palatal plates. In order to facilitate classification process, even one criteria that meets the features of each class will put the ES into the respective socket type. For instance, a socket with ideal clinical and radiographic parameters but gingival recession of more than 4 mm would be considered as a class III

	Single-rooted extraction socket classification		
	Class I	**Class II**	**Class III**
Etiology	Non periodontal	Mild periodontal or endo-perio lesion	Severe periodontal or endo-perio lesion
Gingival recession (mm)	≤3	–	>3
Soft tissue phenotype	Thick	Thin	–
Buccal bone width (mm)	≥2	<2	–
Buccal bone loss	Intact	<50%	>50%
Interproximal bone loss	No	Yes	–
Apical pathology	No	Yes	–
Root position	Adjacent to vestibular plate/at the center	Adjacent to palatal plate	At least 2/3 of the root engaging both buccal and palatal plates

interproximal bone dictates the presence or absence of the soft tissue and interproximal papillae.

3.5.2 | Soft tissue

Soft tissue phenotype (previously named biotype)

Four ES classifications pointed out to the important role of the tissue phenotype.[6,17,21,23] This is because tissue phenotype plays an important role in the implant esthetics. In general, thick tissue phenotype often achieve better esthetic outcomes as well as to be more inclined to IIP.[6] However, for a thin tissue phenotype, more conservative approaches are often suggested to minimize the potential esthetic challenges.

Buccal soft tissue level/loss

The destruction and amount of the remaining soft tissue was included in six classifications.[4,6,16,18,21,24] This variable was assessed qualitatively in all studies except, in the classification by Juodzbalys et al.,[6] it was stated that a soft tissue loss of more than 2 mm contributes to a poor prognosis for ESs.

Soft tissue quality

This consisted of soft tissue predictability which was proposed by Caplanis et al.,[23] and the soft tissue quality by Juoudzbalys et al.[6] The former comprises evaluation of various factors affecting the outcomes of future soft tissue and the latter refers to qualitative features of the soft tissue such as consistency, color, and contour.

Blood supply

One of the included systems took the blood supply to the ES into account in the classification.[10] This concept was investigated by Al-Hezaimi et al.,[10] and they suggested that the blood supply to the ES is derived from interdental bone (the internal walls of the socket) and this is an important factor in terms of the soft tissue contours and prevention of bone resorption. Thus, the presence of adjacent (proximal) teeth serves an important consideration in maintaining the blood supply to the area.

3.5.3 | Patient- and tooth-related factors

Etiology, pathology, and systemic factors

The presence of socket pathology prior to extraction and the etiologic factors were only considered in three classifications.[4,23,24] This mainly consisted of pre-extraction evaluation of the systemic health and risk factors and the cause of extraction (e.g., infection, fracture, etc.) which can affect the prognosis of the treatment. Generally, none of the classification systems clearly mentioned the exact factors to consider. Finally, in one classification system the authors considered the esthetic concern of the patient as one of the main factors.[21]

3.6 | Evaluation tools

All classification systems performed the socket evaluation using clinical and radiographical findings. Moreover, some classification systems specifically mentioned the CBCT images should be taken and evaluated[18] whereas in others the necessity of CBCT image acquisition was not

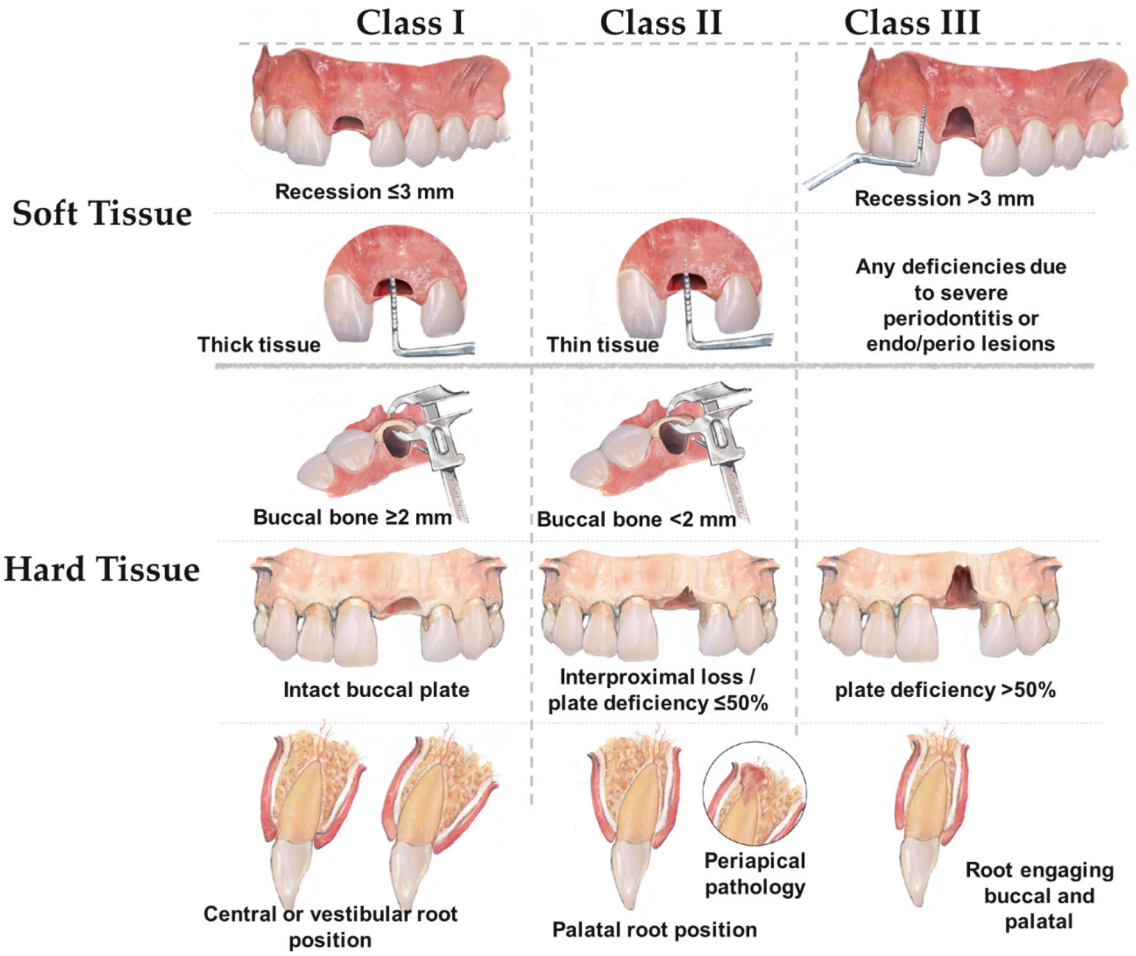

FIGURE 3 the new single-rooted extraction socket classification system. (note that the presence of even one criterion from each class will put a socket into that group. For instance, more than 50% of buccal bone deficiency, even without presence of gingival recession of >3 mm would still be considered as a class III socket)

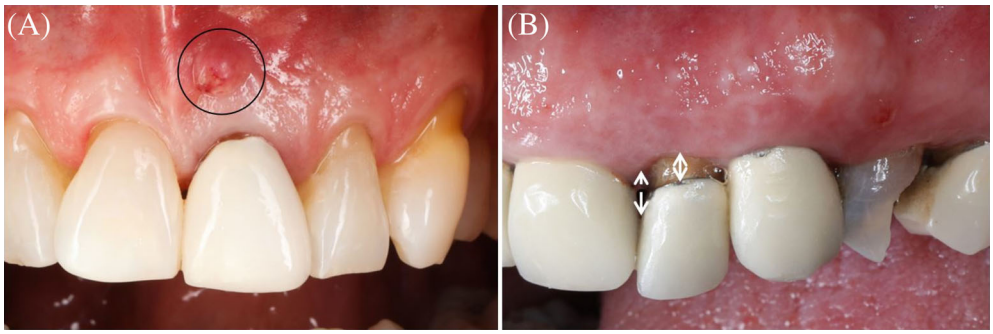

FIGURE 4 Clinical evaluation of the ES prior to the extraction. (A) a chronic fistula and presence of interproximal attachment loss. Based on clinical findings this would be put into class II. (B) More than 3 mm of gingival recession and interproximal attachment loss in a class III socket tooth. ES, extraction socket

stated. In one classification, the authors utilized a prefabricated prosthetic guide to evaluate the hard and soft tissue around the socket.[23]

4 | PROPOSAL OF A NEW CLASSIFICATION SYSTEM

Based on the proposed quality assessment and critical appraisal, and also, taking the latest consensus reports[7,25–28] into consideration, a new single-rooted ES classification was proposed. The new classification system is presented in Table 4 and Figure 3. This consists of three main steps to apply as follows:

The first two steps determine the sockets' class based on the morphologic and anatomical features. The first step is determining clinical factors with regards to ES (Figure 4):

1. Determining the etiology of extraction: extractions with the etiology of excessive caries, endodontic failure, root fractures yield superior prognosis compared to tooth loss due to severe periodontitis or severe endo-perio lesions (Figure 4A).[25]

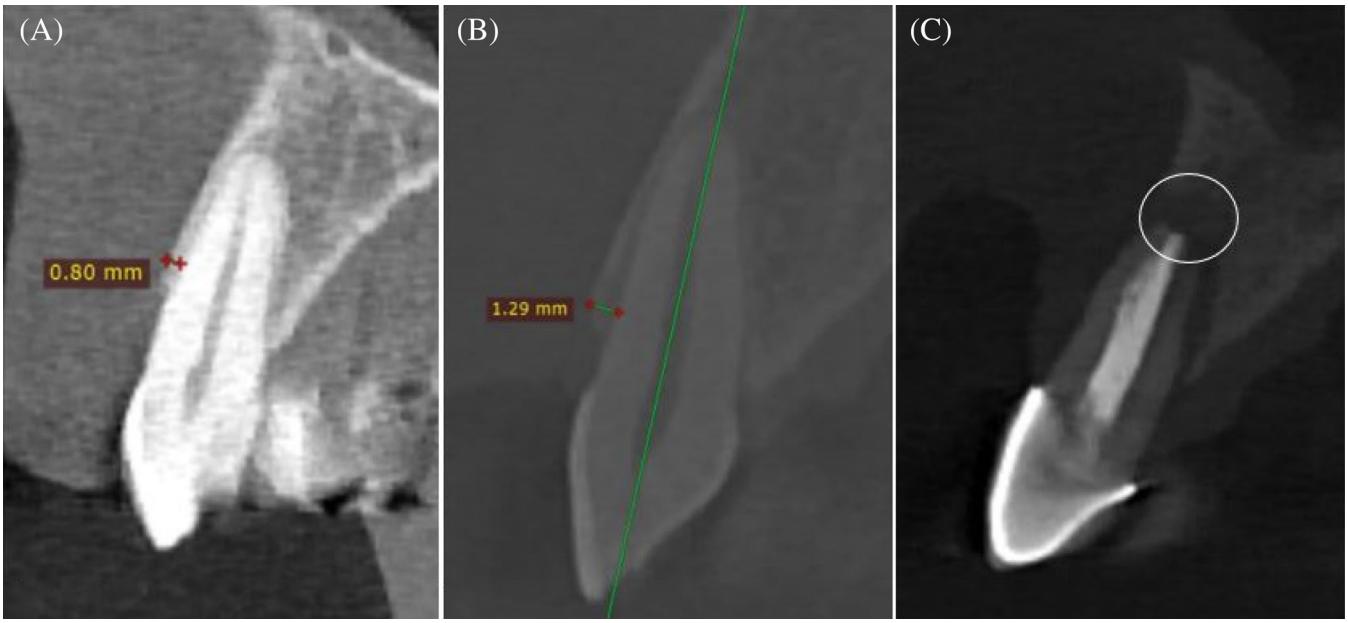

FIGURE 5 Examples of radiographic evaluation of the future ES prior to extraction. (A) A future class II extraction socket with thin (<1 mm) buccal bone thickness and moderate buccal plate dehiscence (<50%). (B) A class II socket with buccal bone thickness between 1 and 2 mm and sagittal root position adjacent to the vestibular plate. (C) A class III socket with more than 50% of buccal bone dehiscence and an apical lesion. ES, extraction socket

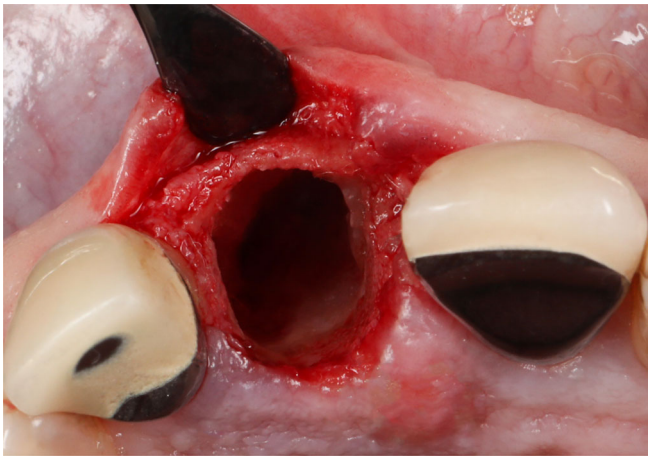

FIGURE 6 The third step of the extraction socket classification: evaluation of the post-extraction socket to confirm the classification. This consists of confirming the amount of remaining buccal bone as well as interproximal plates and the apical topography

2. The amount of gingival recession at the extraction site. A gingival recession of more than 3 mm is considered to be associated with risk of soft tissue deficiency following IIP[6,29] (Figure 4B).
3. Determination of soft tissue phenotype: this parameter can be either thin or thick and plays a key role in determination of future peri-implant soft tissue.[25,27]

Following the clinical examination, the radiographic examination can be performed based on available radiographs and CBCT as the second step (Figure 5).

1. Buccal Bone: the thickness and amount of dehiscence should be considered. Up to 50% of buccal plate loss could be manageable if IIP is considered (Figure 5A,B).[25]
2. Interproximal bone loss: is especially important in the esthetic zone as it contributes to future papilla fill and prevents future interproximal soft tissue defects.[30]
3. Apical Lesions: current evidence indicates favorable success rates for IIP in sockets with periodontal lesion and/or periapical pathology.[31,32] However, before placing the implant careful and thorough decontamination and removal of the infected tissue is required[25,27] (Figure 5c).
4. Root position: this parameter predicts the future three-dimensional position of the implant. In IIP more palatal/lingual positioning of the implant is desired to avoid excessive contact with the residual buccal plate[25,27] to fulfill "prosthetically driven" concept[33,34] (Figures 3 and 5).

Following the second step the initial classification of the socket can be achieved. This allows the dentist to preliminarily diagnose and perform treatment planning. Nevertheless, if the tooth is extracted, the third step (Figure 6) can be initiated, which considers possible class modifiers that are only examinable following removal of the tooth and by inspection of the residual socket, based on possible events during extraction surgery and future implant osteotomy factors, patient-related factors, and also any adverse events during the extraction following criteria:

1. Presence of poorly controlled systemic disease: factors such as diabetes mellitus, smoking and advanced autoimmune conditions may affect the socket healing process as well as pregnancy or adolescence. Therefore, in such scenarios caution would be required.[25]

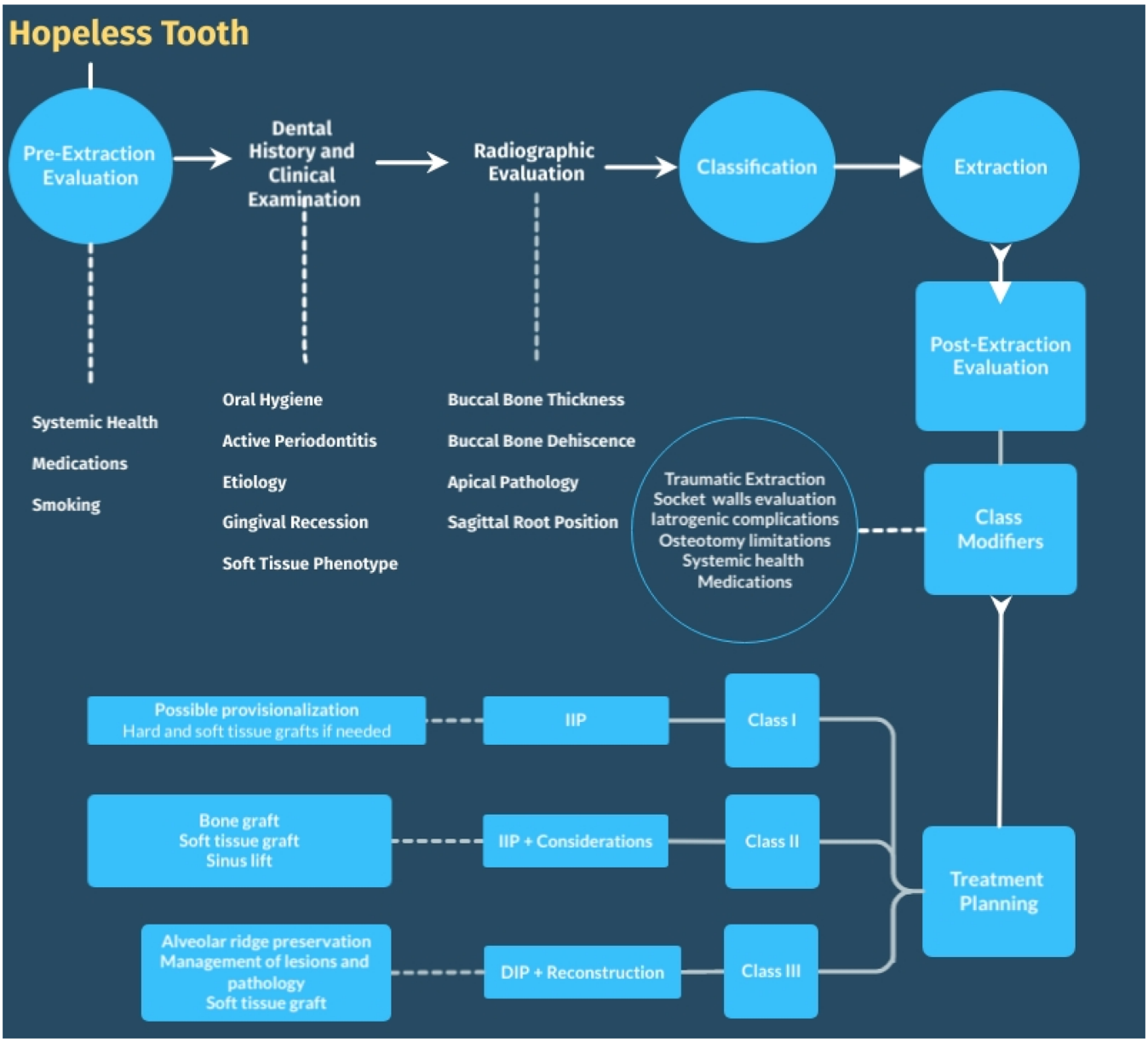

FIGURE 7 The suggested flow-chart to follow for the management of extraction sockets. DIP, delayed implant placement; IIP, immediate implant placement.

2. Smoking: smoking more than 10 cigarettes per day would be considered as a risk indicator in the IIP.[32]
3. Medication history: if the patient takes any medications which can affect favorable healing of the socket, despite scarcity of the literature supporting this point of view, in certain cases (such as bisphosphonate, chemotherapy agent, etc.), caution is necessary.[25,35]
4. Presence of active periodontitis in the same sextant. Although data regarding detrimental impact of previous periodontitis on IIP is controversial[27,36,37] presence of active periodontitis within the same sextant could serve an additional risk for IIP.[38,39]
5. Evaluation of oral hygiene: poor oral hygiene may increase the failure and complications in IIP.[5]
6. Any major trauma during the procedure; which causes failure in preservation of hard and soft tissue quality.[40]
7. Occurrence of iatrogenic complications: such as sinus membrane perforation, buccal plate fracture, and so forth.
8. Re-evaluation of buccal bone thickness and bone quality. This step is advised to be followed in order to re-evaluate and confirm the pre-extraction diagnosis and apply any changes if needed.
9. Osteotomy related factors: including the presence of possible limitations in osteotomy sequence of implant (e.g., risk of damage to the adjacent root or nerves,[41] location of nasopalatine canal, etc.).[28,42]

Lastly, based on the proposed classification system, a decision-making flowchart is presented in Figure 7 demonstrating the suggested approach in the management of ESs. (Table 5)

TABLE 5 Extraction socket class modifiers. The modification proceeds the classification step. This aims to include factors that are not properly examinable prior to the extraction and designed to adjust the initial classification if required. These can be divided into patient-, extraction- and osteotomy-related factors. If the extraction process occurs invasively and cause any damage to the adjacent structure this will transform class I and II to class III. Similar scenario is applicable for iatrogenic complications such as nerve damage or sinus floor perforation. Finally, post extraction evaluation of the socket is required to determine whether it is possible to place implant in the correct position in correspondence to adjacent structure (nerve proximity, etc.) and if not possible, classes I and II will be considered as class III

	Post-extraction class modifiers		
Patient-related factors	Active periodontitis in the same sextant		Class I and II to III
	Poor oral hygiene		Class I and II to III
	Medications affecting healing		Class II to III
	Poorly controlled systemic disease		Class II to III
	Smoking	More than 10/day	Class I and II to III
Extraction-related factors	Invasively traumatic extraction (extensive bone removal)		Class I and II to III
	Iatrogenic complications (sinus floor damage, nerve damage, Buccal plate fracture)		Class I and II to III
	Post-extraction evaluation of buccal bone thickness and bone quality		If compromised, Class I and II to III
Osteotomy-related factors	Possible limitations in implant osteotomy (nerve proximity, adjacent roots, etc.)		If IIP not possible, Class I and II to III

5 | DISCUSSION

This article systematically reviewed all single-rooted ES classifications and proposed a new classification based on a critical appraisal and quality assessment of the previously available systems and with the aim of providing a system with combination of all crucial parameters to consider while performing dental extractions in the esthetic zone.

It is important to be able to discuss the treatment planning prior to the extraction of the tooth. This emphasizes the need for a classification system allowing to classify before the extraction. However, most of the existing ES classification systems lack this feature. Thereby, the introduced new classification system in this paper, allows clinicians to perform the initial classification prior to extraction (as demonstrated in Figures 4 and 5) and next, if proceeded to extraction, one can modify the class by the mentioned class modifiers accordingly (Figure 6). Needless to mention that a critical step (step 3) consists of clinically confirming the pre-extraction determined class by inspection.

Unfortunately, the importance of possible multiple ESs is underappreciated.[43] Although Al-Hezaimi et al.,[10] intended to consider this, the nature of the animal study leaves room for the further research. As a possible approach, condition of the interproximal walls between the adjacent ES was entered into the new ES classification.

All the previous systems, to some extent, covered the anatomical factors affecting the treatment approach. However, it should be noted that there was little attention to the patient related factors such as systemic diseases or smoking or even diabetes, which can easily transform a favorable ES to a questionable despite its undamaged structure. Therefore, one of the main goals of the newly proposed system was to include systemic conditions, as possible class modifiers, following the examination of the anatomical and topographic factors. In a study by Urban et al.,[44] it is indicated that smoking can be a risk factor for molar area IIP. Similarly, it is reported in the literature that despite its acceptable success rate, infectious ES needs adjunctive therapy and additional considerations if IIP is planned.[39,45] Also, it is elaborated throughout the studies that health-related systemic conditions such as diabetes and hypertension could possibly affect the ES healing process and therefore, alter the expected outcomes.[46,47] Therefore, all the aforementioned parameters included as the class modifiers the novel ES classification system.

An important aim of using classifications is to facilitate the communication among all involved parties. This needs the implementation of well-described and precise variables comprising the classification system.[8,48] However, it can be noted that most of the proposed ES classifications assess the defects qualitatively or at best a combination of qualitative and quantitative. This causes discrepancies in terms of diagnosis as it leads to intra- and inter-observer bias as well as several gray zones defining a defect and considering it adequate or compromised.[49] Further investigation on the repeatability of the classifications is suggested. In our classification system, we attempted to provide quantitative and/or dichotomous values for the parameters which increases the reproducibility and quality of assessment.

All included studies implemented radiographic images, either periapical, panoramic and CBCT or combination of these, for the examination of the hard tissue situation and periapical diagnosis. Nevertheless, in terms of the soft tissue evaluation there is a lack of standardized techniques to diagnose. Overall, CBCT images seem to be one of the cornerstones of the ES classification, thus, it is strongly suggested to perform classification by the means of this image modality. And for soft tissue parameters, currently the conventional clinical measurements are suggested.[50]

Lastly, it is suggested that a thorough soft and hard tissue evaluation in combination with patient related factors should be followed. Subsequently, the decision for either IIP or DIP with the suitable modification can be made and applied. Figure 7 illustrates the factors and the flowchart that is suggested to be take into account when performing tooth extractions using the new classification system. That being mentioned, within the limitation of systematic reviews, in this paper

we aimed to merely provide an overview concerning the available classifications and possible gaps within them and describe the characteristics of each one as well as the parameters that are included into each system. Moreover, the readers should bear in mind that the newly introduced classification system is solely based on the most recent consensus reports in implant dentistry[25,28] and despite its benefits in terms of updating the previous systems, it requires further studies to evaluate its validity, responsiveness, and reliability.[11,13,14]

6 | CONCLUSIONS

The present study provided a systematic review and a critical appraisal on the previous single-rooted extraction socket classifications and proposed a new classification system. This classification revises and updates the definitions and criteria from the former systems. An important feature is including the factors affecting future implant treatment, especially in the esthetic zone. Likewise, the most recent consensus-based criteria for immediate implantation such as soft tissue esthetic considerations as well as the sagittal root position was taken into consideration. Lastly, this classification considered the patient-related and extraction-related factors for the first time, as the class modifiers in case they have an impact on the prognosis and treatment planning following the extraction.

DISCLOSURE

The authors declare that they do not have any financial interest in the companies whose materials are included in this article.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon request.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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