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Risk factors associated with short dental implant success: a long-term retrospective evaluation of patients followed up for up to 9 years

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Abstract: This multicenter study aimed to identify the different implant- and patient-related risk factors for long-term short dental implant success. Through a retrospective chart review of three centers, patient information regarding demographic variables, smoking habits, history of periodontitis, systemic diseases, and medications in addition to the parameters for short implant placement including implant manufacturer, design, anatomical location, diameter and length, and type of placement was collected. For statistical analysis, univariate regression models were used at the implant and patient levels. A total of 460 short implants placed in 199 patients followed up for up to 9 years were reviewed. Survival rates of the short implants were 95.86% and 92.96% and success rates were 90% and 83.41% for implant- and patient-based analysis, respectively. Peri-implantitis was reported as the primary cause of short dental implant failure (34/46, 73.91%). Univariate regression models revealed that female sex was strongly related to short implant success. In addition, smoking and history of periodontitis were found to have a significant negative influence on short implant success at the implant and patient levels. Taken together, these results support the use of short implants as a predictable long-term treatment option; however, smoking and history of periodontitis are suggested to be the potential risk factors for short implant success. Therefore, clinicians need to assess these potential risk factors and make treatment decisions accordingly.

Keywords: Dental Implants; Treatment Outcome; Risk Factors; Regression Analysis; Retrospective Study.

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Introduction

The use of standard dental implants has become a highly predictable and effective treatment modality for the rehabilitation of complete and partial edentulism.[1,2,3] Several longitudinal studies have reported high survival rates of approximately 89%–96% over a 10-year period in various patient populations using different dental implant systems. In addition, lower but acceptable success rates varying between 52% and 79% were found in these studies based on the criteria selected for implant success measurement.[4,5,6,7] However, in severe alveolar resorption, standard-length implant (≥10 mm) placement is not possible without additional surgical interventions including bone grafting, sinus floor augmentation, distraction osteogenesis, mandibular nerve transposition, zygomatic implant placement, and transmandibular implant placement. These procedures are associated with increased surgical morbidity, prolonged treatment times, and higher cost.[8,9,10] However, the use of short implants is considered a major contribution to the field of implant dentistry and is a novel therapeutic option for patients with severe alveolar resorption.[9] Although the predictability of short implants was initially controversial because of decreased bone-to-implant contact,[11] several studies have reported short implants to have survival rates similar to those of standard-length implants.[12,13,14]

The adverse effects of tobacco use, chronic hyperglycemia, poor oral hygiene status, periodontitis history, and parafunctional habits on the survival and success of standard dental implants are chronicled in the literature;[3,4,15] however, very few studies have evaluated the risk factors associated with the long-term success of short dental implants.[11,16] Therefore, this multicenter, retrospective study aimed to identify the long-term influence of different implant- and patient-related factors on short implant success.

Methodology

This multicenter, retrospective study included 199 patients (84 men [42.21%] and 115 women [57.79%]; average age: 53.59 ± 10.93 years) referred to the departments of oral and maxillofacial surgery of Ankara Yıldırım Beyazıt University (Ankara, Turkey) and Cumhuriyet University (Sivas, Turkey) in addition to a private practice for implantology in Ankara, Turkey. We examined the clinical files and radiographs of all patients who underwent dental implant placement between December 2007 and August 2016. Patients aged ≥ 18 years who underwent treatment with at least one short implant with a cemented crown or supported cemented bridge were included in the study. Implants were considered short if their length was ≤9 mm.[17] Patients with a history of smoking habits, periodontitis, and systemic disease other than an absolute contraindication to implant surgery were included. However, patients who were undergoing treatment and those with implants noted on radiographic analysis without basic information were excluded from the study. The study protocol was approved by the Ethical Committee of Cumhuriyet University Medical Faculty (2017-10/02).

The surgical technique for implant placement followed a standard protocol under sterile conditions according to the manufacturer's recommendations. Four brands of dental implant systems used at the study centers were evaluated in the study: Straumann (Institute Straumann AG, Waldenburg, Switzerland), Astra Tech OsseoSpeed (Astra Tech AB, Mölndal, Sweden), MIS (MIS Implant Technologies Ltd., Shlomi, Israel), and SGS Dental (SGS International Ltd., Schaan, Liechtenstein).

Data regarding implant manufacturer, design (tissue level and bone level), anatomical location, diameter (ranging from 3.3 to 5.0 mm), length (ranging from 4.0 to 9.0 mm), and placement (immediate and conventional); smoking habits; history of periodontitis; systemic diseases; medications; and survival time were collected and recorded in a database. Implant success was evaluated based on the following criteria proposed by Albrektsson et al.[18]: absence of mobility after implant insertion; no evidence of peri-implant radiolucency; < 0.2-mm annual bone loss following the first year of service; and absence of persistent and/or irreversible signs and symptoms including pain, infection, neuropathy, paresthesia, or any violation of the mandibular canal. Implant survival was defined as the physical existence of any implant in the mouth.

Descriptive statistics and frequency distributions were generated for all demographic variables. Logistic regression models were constructed at the implant and patient levels for statistical analysis of the data. The implant-level model considered each implant as a unit of analysis to determine the influence of implant- and patient-related factors on the success of short implants. Further, the patient-level model considered each patient as a unit of analysis presenting or not presenting an unsuccessful implant. Only patient-related factors were included in the model to determine the factors that best predicted short implant success. Moreover, odds ratios and 95%

confidence intervals were calculated. A p-value of < 0.05 was considered statistically significant, and all analyses were performed using SPSS Statistics, Version 20.0 (SPSS Inc., Chicago, USA).

Results

A total of 460 short dental implants including 344 Straumann, 93 Astra Tech OsseoSpeed, 11 MIS, and 12 SGS implants in 199 patients who were followed up for up to 9 years (6–104 months; average: 33.59 ± 24.44 months) were reviewed in the current study.

Of the included patients, 59 were classified as smokers (29.65%), 58 (29.15%) had a history of periodontitis, 21 had type II diabetes mellitus (DM) (10.55%), and 7 had type I DM (3.52%). Other systemic diseases noted in 46 (23.12%) patients included hypertension (n = 31), arrhythmia (n = 2), asthma (n = 2), hypercholesterolemia (n = 2), hyperthyroid (n = 4), gastric ulcer (n = 2), osteoporosis (n = 1), and rheumatic diseases (n = 2). In total, 263 implants were installed in the maxilla (57.17%) and 197 in the mandible (42.83%); 422 implants were inserted in posterior areas (91.73%). The specific patient and implant characteristics are summarized in Tables 1–3.

Table 1. Frequency distribution of different variables in relation to patients.

Variable	Number of patients (n)	Percentage (%)
Sex		
Male	84	42.21
Female	115	57.79
Age at implant placement (years)		
18–34	11	5.52
35–59	130	65.33
≥ 60	58	29.15
Systemic diseases		
None	125	62.81
Type I Diabetes Mellitus	7	3.52
Type II Diabetes Mellitus	21	10.55
Hypertension	31	15.58
Other systemic diseases	15	7.54
Smoking habits		
No	140	70.35
Yes	59	29.65
History of periodontitis		
No	141	70.85
Yes	58	29.15
Total	199	100

At the end of the study period, a total of 19 implants were lost in 14 patients. The vast majority of implants (16/19, 84.21%) were lost following occlusal loading (late loss) (Table 4). Further, the overall survival and success rates of short dental implants were calculated using implant- and patient-based analysis, with survival rates being 95.86% and 92.96% and success rates being 90% and 83.41%, respectively. Peri-implantitis was reported as the primary cause of implant failure (34/46, 73.91%) (Table 4).

Univariate binary logistic regression revealed that female sex was positively associated with short implant success at the implant (p = 0.009) and patient (p = 0.005) levels. At the implant level, a history of periodontitis (p = 0.021) was negatively associated with short implant success, and the possibility of implant success decreased by 0.934 times per unit with increasing number of cigarettes smoked per day (p = 0.001) (Table 5). At the patient level, a significant negative correlation was found between history of periodontitis and short implant success (p = 0.043), also the possibility of implant success being decreased by 0.920 times per unit with increasing number of cigarettes smoked per day (p = 0.001) (Table 6). The remaining variables did not show a significant correlation with short implant success at the patient or implant level.

Discussion

The use of short implants is based on the biomechanical rationale that most load-bearing stress is generated at the neck portion of an implant, whereas a very small amount is transmitted to the apical portion.[9,19] However, initial clinical research reported lower survival rates for short dental implants than for standard-length implants.[20,21,22] The overall survival and success rates of short implants have increased and their prognosis has become more predictable, possibly due to the recent improvements

Table 2. Smoking status and periodontitis history distribution of patients according to sex.

Variable	Sex					
	Male		Female		Total	
	n	%	n	%	n	%
Smoking habit						
No	58	41.43	82	58.57	140	100
Light smoker (<10 cigarettes/day)	3	23.08	10	76.92	13	100
Moderate smoker (10–19 cigarettes/day)	5	25	15	75	20	100
Heavy smoker (≥20 cigarettes/day)	18	69.23	8	30.77	26	100
Total	84	42.21	115	57.79	199	100
History of periodontitis						
No	49	35	91	65	141	100
Yes	35	60.34	23	39.66	58	100
Total	84	42.42	114	57.58	199	100

Table 3. Frequency distribution of different variables in relation to short implants.

Variable	Number of patients (n)	Percentage (%)
Manufacturer of short implant		
Straumann	344	74.78
Astra Tech OsseoSpeed	93	20.22
MIS	11	2.39
SGS	12	2.61
Total	460	100
Anatomical location		
Anterior mandible	4	0.87
Posterior mandible	193	41.96
Anterior maxilla	34	7.39
Posterior maxilla	229	49.78
Total	460	100
Design of implant		
Tissue level	204	44.34
Bone level	256	55.66
Total	460	100
Implant placement		
Conventional	415	90.22
Immediate	45	9.78
Total	460	100

in the mechanical properties and surface morphologies of implants.[9,10,11,16] This retrospective study aimed to determine the survival and success rates of short dental implants and evaluate the local and systemic risk factors associated with long-term implant success in patients followed up for up to 9 years. Only a few studies in the literature have investigated the long-term prognosis of short implants. In addition, the definition of short implants varies among these studies. Some studies regarded 10-mm-long implants as short implants, and most other studies only included implants of 8- and/or 9-mm length.[23,24,25] In the current study, we regarded ≤9-mm-long implants ranging from 4 to 9 mm in length as short implants. The results of this study demonstrated high survival and success rates in implant- and patient-based analyses, consistent with the findings of other long-term studies.[9,11,26] Similarly, systematic reviews and a meta-analysis of short implants reported high survival and success rates ranging from 88.1% to 100% and 89.5% to 100%, respectively.[8,27,28] Conversely, most reports only specified simple survival and success rates of short implants in a favorable patient population without considering other components that negatively impact implant success.[23,29,30] Additionally, literature assessments of potential risk factors for short implant success/survival with inappropriate statistical analysis may lead to an incorrect conclusion. The main strength of this study is not only its multicenter design comprising a larger patient population than previous studies but also the inclusion of all patients treated with short implants installed at different anatomical locations regardless of their accompanying medical or other conditions. Furthermore, as a statistical method,

Table 4. Distribution of the different variables in relation to failed (unsuccessful) short implants.

Patient					Implant					Implant fail/loss		
Age (years)	Sex	Medical history	Smoking habit	History of periodontitis	Localization	Length (mm)	Diameter (mm)	Design	Placement type	Peri-implantitis	Ex (lost) status	Follow-up (months)
59	F	Healthy	Yes	No	37	8	3.3	BL	Conventional	No	Early loss	3
					36	8	3.3	BL	Conventional	No	No	26
					27	8	4.8	TL	Conventional	No	No	26
68	M	Healthy	No	No	22	8	3.3	BL	Conventional	No	Early loss	4
					26	8	3.3	TL	Conventional	No	Early loss	4
56	M	Healthy	Yes	Yes	14	8	4.1	BL	Conventional	Yes	No	6
55	M	Healthy	No	Yes	47	4	4.8	TL	Conventional	Yes	No	6
					45	8	4.1	BL	Conventional	Yes	Late loss	22
62	F	DM-II	Yes	No	27	8	4.1	BL	Conventional	No	No	12
48	M	Healthy	Yes	No	27	6	4.1	TL	Conventional	Yes	Late loss	12
21	M	Healthy	Yes	No	14	8	4.1	TL	Conventional	Yes	No	14
54	M	DM-I	No	No	27	8	4.8	TL	Immediate	Yes	Late loss	19
53	F	Healthy	No	Yes	46	8	3.3	BL	Conventional	Yes	No	20
47	F	Healthy	No	Yes	14	8	4.1	BL	Conventional	No	No	20
65	M	Healthy	No	Yes	36	8	3.3	BL	Conventional	No	No	24
55	M	DM-II	No	No	46	9	3.5	BL	Conventional	Yes	Late loss	27
69	M	Healthy	No	Yes	26	8	3.3	TL	Conventional	Yes	Late loss	27
50	M	Healthy	Yes	Yes	16	6	4.1	TL	Conventional	Yes	No	29
					25	6	4.1	TL	Conventional	Yes	No	29
72	F	DM-II	No	Yes	26	8	4.1	BL	Conventional	Yes	Late loss	32
60	M	Healthy	Yes	No	15	8	4.1	TL	Conventional	No	No	34
44	M	Healthy	No	No	26	6	4.1	TL	Conventional	Yes	No	36
					16	6	4.8	TL	Conventional	Yes	No	39
55	M	Healthy	No	No	37	8	3.75	BL	Conventional	Yes	No	37
49	M	Healthy	Yes	Yes	16	9	4.5	BL	Conventional	Yes	Late loss	38
					23	9	4	BL	Conventional	Yes	No	52
57	M	Healthy	No	Yes	26	8	3.3	TL	Conventional	Yes	Late loss	42
					16	8	3.3	TL	Conventional	Yes	Late loss	49
49	F	Healthy	Yes	Yes	15	8	4.1	TL	Conventional	Yes	No	43
56	M	Hypertension	No	No	27	8	4.1	BL	Conventional	No	No	49
42	F	Healthy	Yes	No	24	8	4.1	TL	Conventional	Yes	Late loss	51
					26	8	4.1	TL	Conventional	Yes	Late loss	51
					21	8	4.1	BL	Conventional	Yes	No	57
61	M	DM-I	No	No	36	9	3.5	BL	Immediate	Yes	No	58
54	M	Hypertension	Yes	Yes	35	9	4.5	BL	Conventional	Yes	Late loss	63
					37	9	4.5	BL	Conventional	Yes	Late loss	63
56	M	Healthy	No	Yes	45	8	4.1	BL	Conventional	Yes	No	67
65	M	DM-II	Yes	Yes	36	9	4.5	BL	Conventional	Yes	Late loss	72
50	F	Healthy	No	No	25	9	3.5	BL	Conventional	No	No	79
					26	9	4.0	BL	Conventional	No	No	79
64	M	Healthy	No	Yes	36	9	3.5	BL	Conventional	Yes	No	84
47	F	Healthy	No	No	27	9	5.0	BL	Conventional	Yes	No	85
65	M	Hypertension	Yes	Yes	27	8	5.0	BL	Conventional	Yes	No	85
47	M	Healthy	Yes	No	15	9	3.5	BL	Conventional	Yes	No	85
48	M	Healthy	Yes	Yes	26	9	5.0	BL	Conventional	Yes	Late loss	90
					34	9	3.5	BL	Conventional	Yes	Late loss	90

Table 5. Univariate binary logistic regression for short implant success at the implant level.

Variables	B	SE	Wald	p-value	OR	95%CI for OR	
						Lower	Upper
Implant manufacturer	−0.454	0.332	1.877	0.171	0.635	0.332	1.216
Anatomical location of implant	−0.282	0.206	1.881	0.170	0.754	0.504	1.129
Implant diameter	−0.014	0.409	0.001	0.972	0.986	0.443	2.196
Implant length	0.283	0.217	1.696	0.193	1.327	0.867	2.031
Implant design	0.630	0.468	1.808	0.179	1.877	0.750	4.702
Implant placement	0.358	0.708	0.255	0.613	1.430	0.357	5.728
Sex (female)	1.119	0.427	6.869	0.009	3.060	1.326	7.064
Age (years)	−0.025	0.019	1.595	0.207	0.976	0.939	1.014
History of periodontitis	−0.922	0.400	5.303	0.021	0.398	0.182	0.872
Smoking habit	−0.068	0.012	30.905	0.001	0.934	0.912	0.957
Diabetes mellitus	0.196	0.385	0.258	0.611	1.216	0.572	2.588
Other systemic diseases	2.803	0.910	9.499	0.052	16.499	2.775	98.096
Intake of medication	1.683	0.852	3.904	0.058	5.381	1.014	28.565

B: beta coefficient, SE: standard errors, OR: odds ratio, 95%CI: 95% confidence interval.

Table 6. Univariate binary logistic regression for short implant success at patient level.

Variables	B	SE	Wald	p-value	OR	95%CI for OR	
						Lower	Upper
Sex (female)	1.357	0.48	7.997	0.005	3.885	1.517	9.95
Age (years)	−0.032	0.022	2.214	0.137	0.968	0.928	1.01
History of periodontitis	−0.921	0.456	4.085	0.043	0.398	0.163	0.972
Smoking habit	−0.083	0.02	17.433	0.001	0.92	0.885	0.957
Diabetes mellitus	0.176	0.469	0.141	0.707	1.193	0.476	2.99
Other systemic diseases	2.478	1.092	5.15	0.053	11.915	1.402	101.272
Intake of medication	1.882	1.104	2.907	0.088	6.565	0.755	57.104

B: beta coefficient, SE: standard errors, OR: odds ratio, 95% CI: 95% confidence interval.

univariate regression analyses were performed to identify the relationship between each independent implant- and patient-based variable and short implant success separately. In the regression models, only female sex, history of periodontitis, and smoking were shown to significantly affect short implant success in implant- and patient-based analyses.

Periodontitis is an inflammatory condition of the periodontium in which the host immune inflammatory response induced by bacterial colonization leads to the release of several inflammatory mediators, resulting in connective tissue destruction and bone resorption.[4,31] Some studies have asserted that patients with a history of periodontitis have a higher risk of exposure to biological complications (i.e., peri-implantitis and marginal bone loss) and demonstrate lower implant success and/or survival rates than periodontally healthy patients.[2,4,32,33] In the current study, peri-implantitis was shown to be the primary cause of short implant failure, and approximately 44% of these cases occurred in patients with a history of periodontitis, corroborating the findings of previous studies. Nevertheless, only a few studies have reported the influence of periodontitis on the success rate of short implants.[9,29,34] In the studies by Omran et al. and Correia et al., no significant differences were found in terms of survival rates of short implants between patients with or without a history of periodontitis.[9,34] On the contrary, the present study observed a significant negative relationship between a history of periodontitis and short implant success. The implant- and patient-based analyses indicated that patients with a history of periodontitis are at a greater risk of short dental implant failure. A recent prospective study reported similar results in which a great majority of participants had chronic periodontitis (77.1%), and the authors concluded that proper periodontal treatment prior to implant placement is necessary for patients with periodontitis and that a strict, supportive periodontal program is strongly recommended for the long-term success of short implants.[29]

The deleterious effect of smoking on oral health is well documented in the literature. Smoking increases the expression and deposition of advanced glycation end products in the periodontal tissue followed by the upregulation of pro-inflammatory cytokines (i.e., matrix metalloproteinase-1, interleukin-1β, and interleukin-6), promoting tissue damage, development of periodontal diseases, and alveolar bone resorption.[16,35] Additionally, smoking has been reported as a primary patient-related risk factor for dental implant loss,[35] and several studies have found lower implant success and/or survival rates in smokers than in nonsmokers,[1,3,4,9,32,33,36,37] supporting the present study findings of a significant association between smoking and short implant success. According to implant- and patient-based regression analyses, short implant success is 0.934 and 0.920 times less likely to occur in smokers than in nonsmokers, respectively. Further, some studies did not observe a significant relationship between smoking and implant survival.[2,38] In a recent clinical study, Abduljabbar et al.[16] compared clinical and radiographic inflammatory parameters of short implants and reported no significant differences between smokers and nonsmokers. However, the study comprised relatively young males (aged approximately 40 years) whose smoking history consisted of no more than nine packs annually. Additionally, all participants underwent biannual supportive periodontal therapy and were instructed to maintain satisfactory oral hygiene. Although the outcomes of this study stress the importance of strict oral hygiene maintenance protocols among smokers, further studies including patients belonging to various age groups and different smoker types are required to verify the correlation between short implant success and oral hygiene maintenance protocols. Furthermore, strong evidence shows that smoking poses a greater risk of biological implant complications, i.e., peri-implant diseases.[32,35,36,39] In the present study, smokers comprised more than half of peri-implantitis cases (52.94%), supporting the findings reported by Rinke et al.[40] who reported an increased rate of peri-implantitis among smokers and those by Karoussis et al.[6] who reported a 31-fold higher risk of peri-implantitis among smokers than among nonsmokers.

In the recent literature, the influence of sex on dental implant therapy success remains controversial. Although several studies have reported no significant sex-specific differences in terms of implant failure rates,[3,11] some have reported a strong correlation between male sex and implant failure.[37,41,42] In the current study, female sex had a significant positive association with short implant success, possibly explained by the lower rate of a history of periodontitis and heavy smoking in females than in males.

Chronic hyperglycemia is a well-known risk factor for dental implant therapy, and consensus shows that dental implants can remain clinically and functionally stable over a long period in hyperglycemic patients under optimal glycemic control.[1,3,4] However, very few studies on short implants have included diabetic subjects or examined the influence of DM on short implant success. In a study by Omran et al.,[9] DM was not found to have a significant impact on short implant survival. In addition, a recent clinical study with a 3-year follow-up observed no significant difference in terms of clinical and radiographic parameters of short implants between patients with and without type II DM.[10] Similar to these results, the current study found that neither type I nor type II DM is a risk factor for the long-term success of short implants.

Greater bone-to-implant contact has been achieved with the development of implant surface modifications, leading to higher success rates of short implants than shorter machine-surfaced implants.[8,23,30,38] In this study, four short implant systems with different types of surface roughness were examined, and the success rates of all four short implant brands were comparable. Similar results have also been presented in other studies comparing short implants with different designs and surface characteristics.[9,43]

In the current study, although mandibular short implants (92.89%) had a higher success rate than maxillary short implants (87.83%), maxillary insertion of short implants was not found to be a risk factor for implant success. In contrast to this finding, Villarinho et al.[44] indicated that short implants placed in the posterior mandible region showed a higher risk of failure than those placed in the posterior maxilla region. However, many other studies have reported no difference in terms of survival rates of short implants with regard to their anatomical location.[8,9,11] Furthermore, neither implant length and diameter nor the type of implant placement (conventional and immediate) was found to have a significant impact on short implant success in the present study. In a systematic review, Telleman et al.[28] reported higher estimated survival rates with the increasing length of short implants placed in partially edentulous patients. On the other hand, many clinical trials and retrospective studies have reported results similar to those of the current study[9,11,26] and advocated that length and/or diameter are not significant factors affecting short implant survival. Moreover, limited information is available regarding the influence of immediate placement on the success or survival of short implants. A prospective study reported that four of five losses occurred with immediately placed short implants. However, the overall survival rate of short implants was also found to be lower (80%) than that reported in recent studies, possibly attributed to the design of the implants used in that study.[45] More recently, Anitua et al.[11] investigated the impact of individual variables on short implant success in which immediate placement was examined in a "special techniques" category that included sinus elevation and split-crest expansion. Although this group included very few implants (n = 11), which may reduce the power of statistical analysis, no relationship was reported between the implementation of special techniques and short implant success. In the present study, a total of 45 short implants were immediately placed, and only three failures were observed during the follow-up period.

The findings of the current study may contribute important information to the literature regarding the influence of possible risk factors on the long-term success of short implants. However, some limitations should be considered when interpreting these results. First, this is a retrospective study, which relies on the accuracy and completeness of the data available in patients' charts; this may pose a risk of missing data due to gaps in information or incomplete records. Moreover, only short implants with cement-retained crowns and bridges were included, preventing the ability to determine the influence of different types of restorations on the success of short implants. On the other hand, regardless of any medical condition, smoking habit, or periodontal disease history, all patients treated with short implants were examined with robust statistical analyses, minimizing selection bias and increasing the applicability of the study findings to the general population.

Conclusions

A history of smoking and periodontitis has significant negative influence on the success of short implants. However, there is no evidence to support an association between other potential risk factors and short implant success; therefore, clinicians need to be aware of the potential influence of the associated risk factors and make treatment decisions accordingly.

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