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Original Article

Prediction to the healing of diabetic extraction sockets: a retrospective study

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Abstract: Few studies have identified how the sockets change in diabetic patients post tooth extraction. The objective of this study was to predict the changes of socket post tooth extraction in diabetic patients. The investigators implemented a retrospective study. The sample was composed of 75 patients who were diagnosed with type 2 diabetes, all of which had a good glycemic control *(HbA1c ≤ 8.0%, before and post extraction)*. The independent variables were age, gender, pathogenesis, tooth position, healing time post tooth extraction, morphology of socket, permanent location of residence, socket width and depth before extraction, alveolar width and height before extraction. The outcome variables were socket width and depth post extraction. Other study variables were alveolar width and height post extraction. Multiple linear regression was used to build the prediction equation. The *P* value was set at 0.05. There was a statistically significant association from "socket width/depth before extraction" and "healing time post extraction" to "socket width/depth post extraction", after adjusting for "alveolar ridge width before extraction", "tooth position" and "gender". The regression equations for estimating the "socket width/depth post extraction" from the "socket width/depth before extraction" and "healing time post-extraction" gave a high squared multiple correlation r^2 of 77.9% and 82.7%. The regression model explains 88.6% and 91.2% of the variability of the data. The results of this study provide reference for when to insert the implant without an excessive delay or Guided Bone Regeneration surgery by the regression equations in diabetics. Future studies will focus on optimizing the equation.

Keywords: Tooth extraction, prediction, multiple liner regression, diabetes, dental implants

Introduction

One of the premises to achieve successful implantation is primary stability, which refers to sufficient bone around the implant. Severe bone defect of the socket cannot supply enough bone to ensure primary stability [1]. Among non-diabetics, the alveolar ridge change of the first three months post extraction accounts for about 70-80% of the total change volume within the next two years. Three months after extraction, the socket reduces about 4.33 mm horizontally and 3.00 mm vertically [2]. However, three months post-extraction, diabetic patients usually show a much more severe socket condition, often requiring Guided Bone Regeneration *(GBR)* or an extended healing time afterwards [3].

In 2013, there were 382 million people who diagnosed with diabetes. This number is expected growing to 592 million by 2035 [4-7]. Type-2 diabetes accounts for about 90% of all the clinical cases [8], and is characterized as a metabolic disorder by hyperglycemia in the context of insulin resistance and relative lack of insulin. What if we can predict the changing tendency of a diabetic socket? Then we can know when to insert the implant without an excessive delay or GBR surgery.

Few studies have identified how sockets change in diabetic patients post tooth extraction. The objective of this study is to build a mathematical model for predicting the horizontal and vertical changes of the socket in diabetic patients.

Materials and methods

Subjects and study design

This is a retrospective cohort study approved by the Ethics Committee of the Forth Military

Table 1. Correlation between socket width/depth and clinical variables *(case number)*

Total		Gender		Age (year)	Healing time after extraction (month)			Residence	
		Male	Female		3-6	6-12	12-24	Urban	Rural
75		56	19	56.4±6.7	17	17	41	53	22
%		74.7	25.3		22.7	22.7	54.6	70.7	29.3
Socket width post-extraction	r	-3.000		-0.023	-0.693			0.040	
	P	0.009		0.846	0.000			0.736	
Socket depth post-extraction	r	0.137		-0.046	-0.851			0.151	
	P	0.243		0.695	0.000			0.195	

Table 2. Correlation between socket width/depth and clinical variables *(case number)*

Total		Tooth position (FDI notation)/Posterior teeth (75)								Cause of extraction	
		16	17	26	27	36	37	46	47	Caries	PP
75		14	5	10	2	14	8	13	9	43	32
%		18.6	6.7	13.3	2.7	18.7	10.7	17.3	12	57.3	42.7
Socket width post-extraction	r	0.235								0.178	
	p	0.042								0.127	
Socket depth post-extraction	r	0.140								0.020	
	p	0.230								0.863	

*PP-Periapical periodontitis.

Medical University and performed in accordance with the ethical guidelines *(Ethics Approval Number: 2015 kq-001 #)*. Only respondents who signed the informed consent form and met the inclusion criteria were included. Patients with type-2 diabetes who demanded implant-supported prosthesis in authors' department were included as the research subjects during the year 2013-2015.

On the first visit, the patients were asked to take a Cone beam computed tomography *(CT)* scans *(Dental)* before tooth extraction and complete a general information form which included age, gender, permanent location of residence, phone number, smoking habit, occupation and systemic disease history. On the second visit, the patients took the second CT scans and received implant surgery. The periods between the two visits were determined by the patients themselves, but not exceed two years.

Inclusion criteria (1) Confirmed type-2 diabetes for more than three years before extraction with a fasting blood glucose value equal to or higher than 7.0 mmol/L; or 2-h plasma glucose equal to or higher than 11.1 mmol/L [9]; (2) Good blood glucose control; maximum Glycated Hemoglobin A1c *(HbA1c)* levels were under 8.0% before and post extraction [10]; (3) No missing teeth or bone defect on either side of the extraction site; no third molar exists for the cases of second molar extraction with an integrated or completely healed retro-molar Pad; (4) Ultrasonic scaling before extraction and no progressive periodontal disease; (5) No hematopoietic, digestive or autoimmune diseases; no glucocorticoid drugs use during surgery; (6) No smoking or has given up smoking for more than three years; (7) Minimally invasive extraction, no infection after extraction in our hospital; (8) Signed informed consent; (9) Complete CT and general information data [11].

The alveolar bone data included alveolar ridge width *(ARW)*, alveolar ridge height *(ARH)*, socket depth *(SD)*, and socket width *(SW)*. Different locations of residence mean different living conditions which could influence the result. Gender and cause of extraction were also considered as interference. So the causes of extraction were divided into caries and periapical periodontitis. Phone calls and clinical review were made to confirm the above information of the included patients (**Tables 1** and **2**).

Clinical parameters

CT data of 75 patients were analyzed with GALAXIS *(Galileos by Sirona)* software. Clinical parameters included ARW, ARH, SD, SW, age, gender, permanent location of residence, heal-

Figure 1. ARH and ARW measurement before extraction. A connecting line was made referencing the buccal and lingual bone peaks as "ideal surface". Then, a point 1 mm under the ideal surface was made. The vertical distance through the point parallel to ideal surface from both bone cortexes was considered as ARW (9.53 mm). In the posterior area of mandible, ARH (16.42 mm) was measured from superior margin of the mandibular nerve tube to ideal surface (Tooth position 36, before extraction).

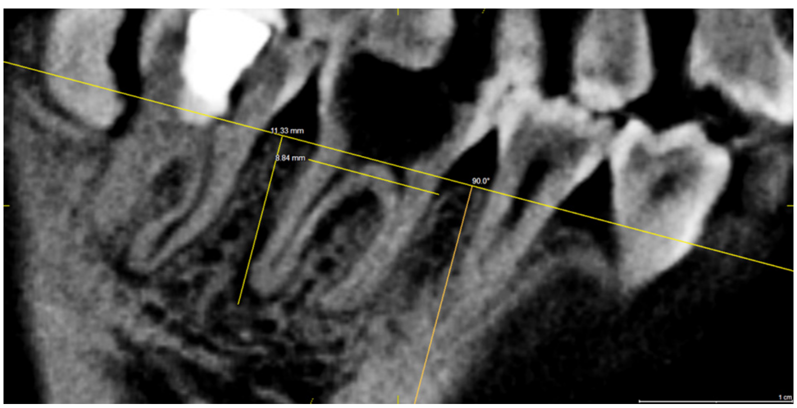

Figure 2. SW_{md} measurement before extraction. In medial-distal direction, a connecting line was made referencing the adjacent bone peaks as "ideal surface". The parallel distance 1 mm under the ideal surface from both edges of socket was considered as SW_{md} (8.84 mm). (Tooth position 36, before extraction).

ing time post-extraction, causes of extraction and blood glucose level [12]. ARW, ARH, SD and SW were measured independently by two calibrated dentists who were blind of the patients' information before and post extraction. The data was then evaluated by two other dentists. If there were disagreement on any results, the four dentists would take additional measurements until an agreeable conclusion is reached. The mean values of the data were recorded [13].

Alveolar ridge width and height

Before extraction: The ARH and ARW were both measured in buccal-lingual directions on CT scans, and the biggest result was chosen. Firstly, a connecting line was made referencing the buccal and lingual bone peaks as "ideal surface". Then, a point 1 mm under the ideal surface was made. The vertical distance through the point parallel to ideal surface from both bone cortexes was considered as ARW. ARH was measured perpendicular to the ideal surface. In the posterior area of maxilla, ARH was measured from maxillary sinus floor to ideal surface. And in the posterior area of mandible, ARH was measured from superior margin of the mandibular nerve tube to ideal surface (**Figure 1**).

Post extraction: The conditions post extraction was more complicated than before. The morphology of alveolar ridge determined the measuring method. For the cases of socket's morphology remained, the method was the same with before extraction.

For the cases of socket's morphology disappeared, marked out the intersection of the bone surface and implant direction. Afterwards, a point 1 mm under the intersection along the implant long axis was made. The vertical distance through the point perpendicular to implant long axis from both bone cortex was considered as ARW. ARH was measured along the estimated implant direction [14].

Socket depth and socket width

Before extraction: SW and SD were both measured in buccal-lingual and medial-distal directions. In buccal-lingual direction, a connecting line was first made referencing the buccal and lingual bone peaks as "ideal surface". Then, a point 1 mm under the ideal surface was made. The distance through the point parallel to ideal surface from both edges of socket was considered as SW_{bl} (**Figure 1**). In medial-distal direction, a connecting line was made referencing the adjacent bone peaks as "ideal surface". The parallel distance 1 mm under the ideal surface from both edges of socket was considered as SW_{md} (**Figure 2**). The bigger result of SW_{md} and SW_{bl} was final SW. SD was measured perpendicular to the ideal surface from the nadir point of the socket to the ideal surface (**Figures 1**, **2**).

Post extraction: SD and SW were measured in buccal-lingual and medial-distal directions and the bigger results were chosen. For the cases of socket's morphology remaining, the method was the same with before extraction

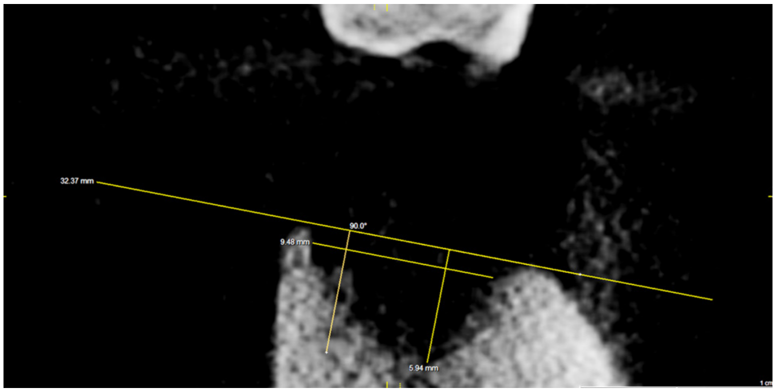

Figure 3. SW_{bl} measurement post extraction. For the cases of socket's morphology remained, the parallel distance 1 mm under the ideal surface from both edges of socket was considered as SW_{bl} (9.48 mm). (Tooth position 37, six months post extraction).

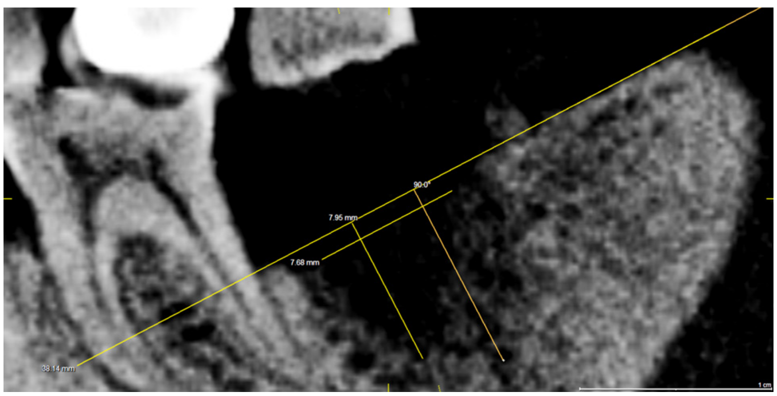

Figure 4. Measurement for cases of second molars extraction. For the cases of second molars extraction, the ideal surface was drawn by referencing the alveolar bone of the retro-molar pad and first molar. (Tooth position 37, six months post extraction).

(**Figures 3**, **4**). For the cases of socket's morphology could not be seen in buccal-lingual direction, the SD and SW were only measured in medial-distal direction. For the cases of second molars extraction, the ideal surface was drawn by referencing the alveolar bone of the retro-molar pad and first molar (**Figure 4**) [14].

When the SD was less than 1 mm, the SW and SD were both recorded as 0. Because the SD of many cases was less than 3 mm, SW was only measured at distance of 1 mm, instead of 1, 3 and 5 mm apical to the crest [2, 15].

Statistical analysis

Microsoft Excel 2011 was used to build the database. Multiple linear regression was used to build the prediction equation. SPSS 17.0 *(Chicago, Illinois, USA)* was used for statistical description and analysis. Differences were considered significant at $P < 0.05$. An adequate sample size was determined to be at least 9 subjects at $\alpha = 0.05$ and $1\text{-}\beta = 80\%$. Results are presented as means ± standard deviation.

The relationship between the "SW/SD post-extraction" *(dependent variable)* and "ARW/ARH post-extraction", "ARW/ARH before-extraction", "SW/SD before-extraction", "healing time post-extraction" and "gender" *(independent variable)* was assessed by linear regression, which was appropriate for the attempts to model the relationship between two or more explanatory variables and a response variable by fitting a linear equation to observed data. The r^2 and the standard error of the estimate were calculated to assess the suitability of the regression equations and the accuracy of predictions.

Table 3. Regression model results include socket width before-extraction, healing time post-extraction, gender and alveolar ridge width before-extraction

Model	Unstandardized coefficients		Standardized coefficients	t	Sig.
	B	Std. Error	Beta		
Constant	1.959	0.959		2.043	0.045
Socket width before-extraction	0.656	0.096	0.495	6.829	0.000
Healing time post-extraction	-0.204	0.020	-0.606	-10.460	0.000
Gender	0.166	0.257	0.038	0.649	0.519
Alveolar ridge width before-extraction	-0.013	0.104	-0.009	-0.124	0.902
Tooth position	0.095	0.241	0.023	0.395	0.694

*Dependent Variable: Socket width post-extraction.

Table 4. Final regression model results include socket depth before-extraction and healing time post-extraction

Model	Unstandardized coefficients		Standardized coefficients	t	Sig.
	B	Std. Error	Beta		
Constant	2.436	0.589		4.137	0.000
Socket depth before-extraction	0.531	0.078	0.330	6.793	0.000
Healing time post-extraction	-0.249	0.014	-0.882	-18.183	0.000

*Dependent Variable: Socket depth post-extraction.

Results

All the clinical variables which might associate with the SW and SD post-surgery went through the correlation analysis. And only "ARW post-extraction" *(r 0.577, P 0.000)*, "ARW before-extraction" *(r 0.394, P 0.000)*, "SW before-extraction" *(r 0.659, P 0.000)*, "healing time post-extraction", "tooth position" and "gender" were correlated to "SW post-extraction" (**Table 1**). Only "ARH post-extraction" *(r 0.309, P 0.007)*, "SD before-extraction" *(r 0.246, P 0.033)* and "healing time post-extraction" were correlated to "SD post-extraction" (**Tables 1**, **2**). "ARH post-extraction" could not be determined before-extraction, so it was an invalid variable.

Following this, and using independent variables from above, multiple linear regression analysis was used to determine a new prediction equation. The significance of "gender", "tooth position" and "ARW before-extraction" were > 0.05, so the three variables were eliminated (**Table 3**). And leave the final equation (Equation 1).

$SW/SD_{post\text{-}extraction} = A + B* SW/SD_{before\text{-}extraction} + C* \text{healing time}_{post\text{-}extraction}$ (A was constant term, B and C were coefficient) (Equation 1)

The regression equations for estimating the "SW/SD post-extraction" from the "SW/SD before-extraction" and "healing time post-extraction" gave a high squared multiple correlation r^2 of 77.9% and 82.7%. And all of the variables are significant by the t tests ($P < 0.05$) (**Tables 4**, **5**). Examination of the residuals indicates no unusual patterns. The inclusion of the "SW/SD before-extraction" and "healing time post-extraction" variables explains 88.6% and 91.2% of the variability of the data. The final equations were as follows *(*Equations 2, 3*)*.

$SD_{post\text{-}extraction} = 2.436 + 0.531* SD_{before\text{-}extraction} - 0.249* \text{healing time}_{post\text{-}extraction}$ ($0 \leq SD_{before\text{-}extraction}$; $3 \leq \text{healing time}_{post\text{-}extraction} \leq 24$) (Equation 2)

$SW_{post\text{-}extraction} = 1.875 + 0.672* SW_{before\text{-}extraction} - 0.206* \text{healing time}_{post\text{-}extraction}$ ($0 \leq SW_{before\text{-}extraction}$; $3 \leq \text{healing time}_{post\text{-}extraction} \leq 24$) (Equation 3)

Discussion

The traditional opinion on implant surgery requires that the thickness of alveolar bone is at least 5.5 mm in the bucco-lingual direction, and the thickness of the buccal/labial and lingual bone is at least 1 mm to ensure both function and aesthetics [16]. Because of pathological change, diabetic patients have a higher probability of periodontitis and tooth loss compared to healthy persons [17]. And showed a poorer socket healing than non-diabetics [3].

Table 5. Final regression model results include socket width before-extraction and healing time post-extraction

Model	Unstandardized coefficients		Standardized coefficients	t	Sig.
	B	Std. Error	Beta		
Constant	1.875	0.717		2.617	0.011
Socket width before-extraction	0.672	0.075	0.507	8.990	0.000
Healing time post-extraction	-0.206	0.019	-0.612	-10.845	0.000

*Dependent Variable: Socket width post-extraction.

This study provides a mathematical model to predict the change of diabetic socket. Under normal circumstances, the socket width is wished to be close to the implant diameter as much as possible. Once the socket width was bigger than the implant diameter, there would be empty space between the implant and the socket side walls. Even though the empty space did not affect the primary implant stability, it also might affect the osseo-integration around the implant neck. GBR technique could be used to fill the empty space around implant neck which may cause marginal bone loss. Meanwhile, the difficulties increased in options to choose implants and position, which lead to esthetic compromises [18, 19].

Bone quality has significant positive correlations with HbA1c level [20]. The results in our study were obtained from diabetic patients with good blood glucose control, *(maximum HbA1c levels under 8.0%)*. If the blood glucose was not controlled well, the implanting condition may become worse.

Delay of implant insertion will increase aesthetic risk and treatment period [21]. In hope to optimize treatment procedure, reduce pain and shorten the program, this model will provide clinical reference.

Conclusions

$SD_{post\text{-}extraction} = 2.436 + 0.531^{*}\ SD_{before\text{-}extraction} - 0.249^{*}\ \text{healing time}_{post\text{-}extraction}$ $(0 \leq SD_{before\text{-}extraction};\ 3 \leq \text{healing time}_{post\text{-}extraction} \leq 24)$

$SW_{post\text{-}extraction} = 1.875 + 0.672^{*}\ SW_{before\text{-}extraction} - 0.206^{*}\ \text{healing time}_{post\text{-}extraction}$ $(0 \leq SW_{before\text{-}extraction};\ 3 \leq \text{healing time}_{post\text{-}extraction} \leq 24)$

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Disclosure of conflict of interest

None.

Authors' contribution

Si-Jia Zhang, Shu-Yan Wang, Ying-Liang Song and De-Hua Li designed the experiments. Si-Jia Zhang and Shu-Yan Wang performed the experiments and analyzed the data. Nai-Wen Tan and Wen-Zhong Zhu analyzed the CT images. Si-Jia Zhang wrote the paper. Ying-Liang Song and De-Hua Li supervised the experiment and revised the paper. All authors read and approved the final manuscript.

Abbreviations

GBR, Guided Bone Regeneration; CT, Cone beam computed tomography; HbA1c, Glycated hemoglobin A1c; ARW, Alveolar ridge width; ARH, Alveolar ridge height; SD, Socket depth; SW, Socket width.

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