A Restoratively Driven Ridge Categorization, as Determined by Incorporating Ideal Restorative Positions on Radiographic Templates Utilizing Computed Tomography Scan Analysis

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ABSTRACT

Background: The introduction of implants into the field of dentistry has revolutionized the way we evaluate edentulous ridges. In an attempt to evaluate the deficient edentulous ridge, numerous classification systems have been proposed. Each of these classification systems implements a different approach for evaluating and planning treatment for the ridge deficiency.

Purpose: The purpose of the present investigation was to propose a restoratively driven ridge categorization (RDRC) for horizontal ridge deformities based on an ideal implant position as determined through implant simulation, utilizing computed tomography (CT) scan images.

Materials and Methods: Radiographic templates were developed to capture the ideal restorative tooth position. Measurements were performed using CT scan software in a cross-sectional view and by virtual placement of a parallel-sided implant with a 3.25-mm diameter.

Results: Edentulous ridges were divided into five groupings: Group I, simulated implants with at least 2 mm of facial bone, accounted for 19.4% of ridges; Group II, simulated implant completely surrounded by bone, with less than 2 mm of facial plate thickness, accounted for 10.4% of ridges; Group III, wherein dehiscences are detected but no fenestrations are present, accounted for 33.3% of ridges; Group IV, wherein fenestrations are detected but no dehiscence is present, accounted for 6.3% of ridges; and Group V, wherein both dehiscences and fenestrations are present, accounted for 30.6% of ridges.

Conclusion: The use of RDRC indicates that a high number of cases in the maxillary anterior area would require augmentation procedures in order to achieve ideal implant placement and restoration.

KEY WORDS: CT scan, implant placement, ridge categorization, ridge defect, ridge deficiency

INTRODUCTION

Deformed partially edentulous ridges compromise ideal implant placement and potentially compromise implant survival. Some common causes of alveolar ridge deformities are traumatic extraction, facial trauma, endodontic apical surgeries, advanced periodontal disease, clefts from birth defects, or implant failures.[1,2]

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DOI 10.1111/j.1708-8208.2008.00125.x

There are several published articles present in the literature, which have presented ridge defect classification systems.[3–5] Utilizing these classification systems can be helpful in planning treatment aimed at correcting ridge defects.[2] Seibert[3] developed a classification of ridge defects based on three broad categories: buccolingual tissue loss, apico-coronal tissue loss, and a combination of both. More recently, Wang and Al-Shammari[4] described a new system, which is a modification of Seibert's, called the horizontal, vertical, and combination (HVC) classification. In the HVC classification system, the defects are subdivided into small (S), medium (M), and large (L) subcategories. Wang and Al-Shammari also described treatment options based on this HVC classification. With the advent and widespread use of dental implants, the careful evaluation of a ridge's available bone volume and corresponding dimension has become extremely important. Several articles have been published in an attempt to discuss this concern. Lekholm and Zarb[5] described a classification, which includes five stages of bone resorption, ranging from minimal to severe resorption. Misch[6] devised a classification system divided into four divisions of available bone. Treatment options were subsequently based on the amount of available bone height, width, and angulation. Tinti and Parma-Benfenati[2] introduced a clinical classification of bone defects. They categorized "the envelope of bone" into five types: extraction wounds, fenestrations, dehiscences, horizontal ridge deficiencies, and vertical ridge deficiencies. They also proposed treatment based on their classification.

Radiographs that can reproduce the ridge in three-dimensional images are available to evaluate hard tissue and to plan implant placement prior to surgery. In a restorative-driven treatment plan, it is important to diagnose the degree of ridge deformity in relation to the ideal implant position and the optimal aesthetic result. To date, no published report has classified ridge deformities according to the projected implants' restorative position. Clinicians should focus on this three-dimensional bone-to-implant relationship in order to establish an ideal and harmonic hard and soft tissue situation that is stable over time. In addition, it is important to consider the thickness of the bone surrounding the implant circumferentially. Published literature contains authors who stress the importance of at least 2 mm of facial plate thickness.[7,8] When the facial plate is less than this critical thickness, the clinician should expect an increased possibility of recession and implant exposure on the facial. This is due to the increased risk of losing the remaining facial plate during bone remodeling. Utilizing three-dimensional images allows for evaluating these potential issues prior to treatment.

The purpose of the present study was to create a categorization system for horizontal ridge deformities based on an ideal restorative position as determined through implant simulation, utilizing computed tomography (CT) scan images.

MATERIALS AND METHODS

Compiling CT Scan Data

The CT scan data obtained for this study were compiled from the Implant Dentistry Database (IDD), established in the Implant Division of the Department of Periodontics and Implant Dentistry at New York University College of Dentistry (NYUCD), Kriser Dental Center. Patients examined in the Implant Division undergo both clinical and radiographic evaluation. Depending on the clinical condition, patients may also undergo a CT scan evaluation when indicated. Each radiographic template was developed by first creating a wax-up of the ideal restorative tooth position. This ideal restorative tooth position was then captured in the radiographic template, thereby allowing the radiographic template to capture the ideal restorative position of the tooth, including the buccal, palatal, incisal, and cemento-enamel junction (CEJ) locations of the crown. The data set used in this study was extracted as de-identified information from the patient's charts in the Implant Division. The IDD was certified by the Office of Quality Assurance at NYUCD. This study is in compliance with the Health Insurance Portability and Accountability Act requirements and was approved by the institutional review board.

To develop a categorization system based on CT scan analysis, inclusion criteria were established to determine the scans to include in the study (Table 1). CT scan images that were unclear were excluded from the study.

One thousand five hundred CT scans were screened from the IDD in the Implant Division at the NYUCD Department of Periodontics and Implant Dentistry. Out of this pool of screened scans, 85 cases satisfied the established selection criteria. These 85 subjects represented 144 implant sites that were incorporated in the analyzed data set.

CT Scan Protocol and Analysis

All the measurements were performed and documented by two independent investigators using CT scan software (SimPlant 8.0, Materialize, Glen Burnie, MD, USA). The software allows viewing the scan in a cross-sectional view. This enables the investigator to examine the planned implant site while visualizing both the buccal and the palatal contours, thereby providing the investigator with the ability to utilize the implant placement simulated feature of the software. A simulated parallel-sided implant with a 3.25-mm diameter and a 10-mm length was positioned in each edentulous area to replace the missing natural tooth. The simulated implants were placed in the ideal implant position to provide for evaluating the relationship to the ideal restorative position. Simulated implants were placed 3 mm below the ideal CEJ as determined from the wax-up and radiographic template in order to provide enough apico-coronal room for an aesthetic emergence profile for the prosthetic replacement.[9]

The following protocol was established and utilized in positioning the simulated implants:

- Mesial-distal position: The implant's location in the arch was determined according to the tooth position as delineated by the markers in the radiographic template.
- Buccal-lingual angulation: The buccal-lingual direction of the implant was ascertained by following the angulation found on the adjacent existing teeth. Therefore, some implants had an incisal edge angulation while others were positioned toward the cingulum.
- Mesial-distal inclination: The mesial-distal direction of the implant was determined by analyzing the adjacent existing tooth/teeth and the ideal position of the tooth as outlined by the radiographic template.
- Apical-coronal position: The implants were placed approximately 3 mm apical to the buccal CEJ of the ideal tooth position as outlined by the radiographic template.

TABLE 1 Computed Tomography Scan Inclusion Criteria

Obtained with a radiographic template.
Showing only maxillary anterior missing teeth.
Showing at least two consecutive missing teeth.
Showing at least one remaining anterior tooth.
Investigate only for horizontal defects utilizing grouping inclusion criteria.

TABLE 2 Edentulous Ridge Investigation Grouping Inclusion Criteria

Group I	The simulated implant is completely surrounded by bone; no dehiscence or fenestration present ≥2 mm of facial plate thickness.
Group II	The simulated implant is completely surrounded by bone; no dehiscence or fenestration present <2 mm of facial plate thickness.
Group III	Dehiscences are detected but no fenestrations are present.
	Group III-A: Either a buccal or a palatal dehiscence is present.
	Group III-B: Both buccal and palatal dehiscences are present.
Group IV	Fenestrations are detected but no dehiscence is present.
	Group IV-A: Either a buccal or a palatal fenestration is present.
	Group IV-B: Both buccal and palatal fenestrations are present.
Group V	Both dehiscences and fenestrations are present.

For data collection, the edentulous ridges were grouped into five categories as shown in Table 2 However, Groups III and IV were divided into two subgroups during the data collection stage to determine if any differences occurred between the buccal and the palatal sides.

RESULTS

The results found from the CT scans analyzed are summarized in Table 3. When the results of Groups I and II are combined, they represent 29.8% of the sites. The combined Group III ridges with a dehiscence were found in 33.3% of the sites. The fenestrated Group IV-A and -B ridges combined occurred in 6.3% of the sites. The nine sites of the Group IV-A subgroup were 100% of the Group IV ridge deformity. Group V ridges containing both dehiscences and fenestrations were present in 30.6% of the implant sites.

From the data, we propose a new ridge categorization system for identifying ridge defects and for determining treatment options for horizontal defects. This

TABLE 3 Results from Computed Tomography Scan Analysis (with a 3.25-mm-Diameter Implant)

Ridge Grouping	Number (Percentage)	Subjects
Group I	28 (19.4)	18
Group II	15 (10.4)	14
Group III-A	30 (20.8)	21
Group III-B	18 (12.5)	9
Group IV-A	9 (6.3)	5
Group IV-B	0 (0)	0
Group V	44 (30.6)	18

categorization system is summarized in Table 4. It has been named the restoratively driven ridge categorization (RDRC). This categorization system is divided into five separate groups, which are based on the divisions created during data collection.

DISCUSSION

The ultimate goal of implant treatment is to surgically place implants in the most desirable position, to maximize the restorative aesthetics, phonetics, and function while providing stable long-term results. Identifying the "optimal final tooth position," prior to treatment, enables the restorative dentist and surgeon to analyze the potential impact of ridge defects. Soft or hard tissue augmentation can be anticipated and performed to help optimize the final results.[10] Treatment with implants in the aesthetic zone should be planned by considering the circumferential bone resorption that often occurs as part of the healing response around the implant head. The literature discusses the necessity for the bone on the buccal side of an implant to be at least 2-mm thick.[8] This thickness helps provide the bone required to reduce recession at the crest of the implant and thereby also to reduce aesthetic failures.

The decision was made to compile only horizontal defect data because it was surmised that vertical defects were more readily visible and that vertical defects will show up as dehiscences in the documentation process. A vertical defect is present whenever a clinician observes the crestal bone level situated more than 3 mm away from the ideal CEJ position. Clinically, a clinician maybe more cognizant of case difficulties and does not face the same decision dilemmas with vertical defects. Vertical defects were not included in this study or in the resulting ridge categorization because vertical defects by their nature require bone grafting. While vertical defects affect the spatial position of the implant in an apico-coronal direction, it is the horizontal defect that plays a larger role in implant position and angulation issues. These issues correspondingly affect the potential future recession and aesthetics of the implant.

Recognizing the potential types of horizontal defect issues prior to implant placement is a critical component in planning treatment for a patient. Using this new ridge categorization system will enhance identifying horizontal ridge defects and will help provide guidance to the clinician in developing treatment requirements.

The results illustrate that, from the cases in our study, only 19.4% of the simulated 3.25-mm-diameter implant sites had 2 mm or more of facial bone. The remaining 80.4% of implant sites had some degree of horizontal loss. Therefore, when horizontal defects are present, most cases will require some degree of ridge augmentation, especially in the aesthetic zone. According to our IDD CT scan data, 81% (116 of the total 144) of the implant sites studied were identified as requiring grafting procedures. This may be due in part to the preexisting anatomy and ridge resorption pattern in the maxillary anterior area.[11,12] However, deformities in the anterior part of the maxilla may be related to the periodontal biotype, genetic characteristics, trauma, iatrogenic damage of the bone, or other reasons independent of the maxillary resorption. It is also important to note that the limited number of cases present in our study that did not require graft procedures was

TABLE 4 Restoratively Driven Ridge Categorization (Ridge Categorization for Horizontal Defects Utilizing Computed Tomography Scans)

Group I	Simulated implant is completely surrounded by bone – with 2 mm or more facial plate thickness.
Group II	Simulated implant is completely surrounded by bone – with less than 2 mm of facial plate thickness.
Group III	Dehiscences are detected on either buccal and/or palate. No fenestrations are present.
Group IV	Fenestrations are detected on either buccal and/or palate. No dehiscence is present.
Group V	Simulated implant with a dehiscence and fenestration defect.

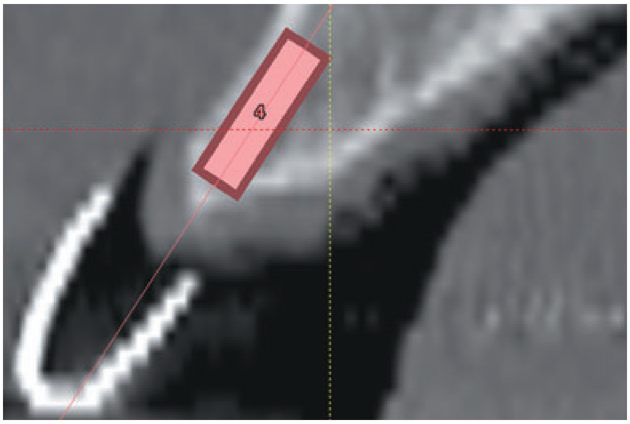

Figure 1 A Group II ridge defect: The simulated implant is completely surrounded by bone, although the facial plate is less than 2-mm thick.

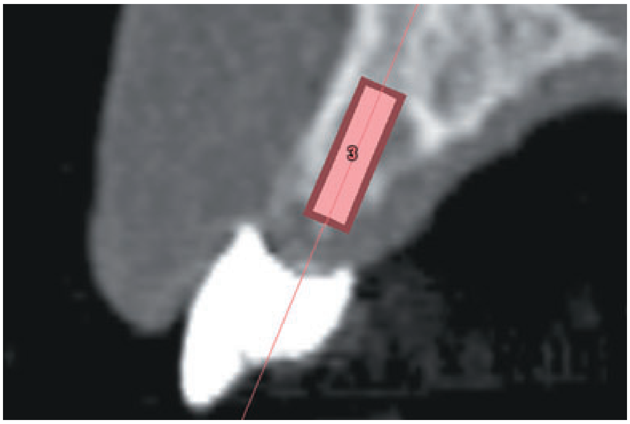

Figure 2 A Group III ridge defect: The simulated implant has a palatal dehiscence at the coronal aspect. The vertical line depicts a screw-retained crown. A cemented crown or an angled abutment in this case could help improve this site's classification rating.

determined utilizing a 3.25-mm-diameter simulated implant. A 3.25 × 10.0 mm implant was selected as the guide implant because, according to the literature, this is the smallest permanent implant with a high success rate.[13,14] However, the use of conventional diameter implants most likely would have resulted in a greater number of ridge defects and complications than those reported in the present study population. Based on the frequency of ridge deformities documented in the present study, procedures for ridge augmentation should be considered when necessary to obtain predictable results.

The Group I ridge is the only classification that does not require any augmentation prior to implant placement. Unfortunately, this classification represents a small portion of the implant sites likely to be encountered in the maxillary anterior region. A Group II ridge may require some type of augmentation (Figure 1). This class has many potential treatment options that may suit the proposed defect. When a Group II defect is encountered, it is important to determine the degree of bone that is still present. When the defect is only slightly less than the ideal 2-mm facial thickness, the clinician needs to weigh no additional treatment versus perhaps placing a connective tissue graft or a bone graft. As the bone loss increases though and starts approaching closer to 1 mm of remaining facial thickness, a bone graft needs to be considered with or without a connective tissue graft. However, this graft can be performed at the time of implant placement because of the limited grafting required. Therefore, the Group II ridge is a challenge in regard to planning out the treatment steps that will best provide the site with long-lasting results.

The ridges of Groups III, IV, and V (Figures 2–5) may all require bone grafting to provide the proper implant site if a stable aesthetic treatment outcome in the long run is to be predicted. The question becomes "What is the desired long-term outcome" and "What criteria will be used to determine success?" Implant success has been grouped according to a scale that evaluates implant health[15]; however, this scale does not address aesthetic success. The aesthetic component is a crucial aspect of long-term clinical success. If an implant has recession that allows exposure of the metal collar or threads in an aesthetically demanding patient, the implant may be well osseointegrated, but is it a success? If an implant is placed in the aesthetic zone with an

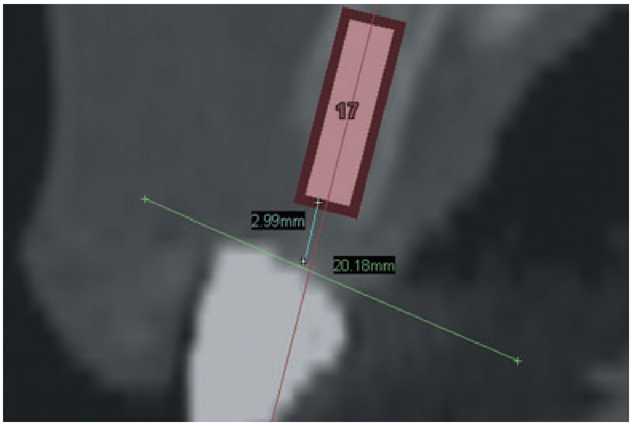

Figure 3 A Group III ridge defect: The simulated implant displays a facial dehiscence defect. Notice that the implant placement is approximately 3 mm from the CEJ of the planned restoration.

insufficient volume of bone to maintain soft tissue levels after biologic width remodeling, it can potentially become an implant aesthetic failure even though it is a functional success. The treatment necessary for implant sites in groups III, IV, and V should be determined based on evaluating the long-term results desired.

Concerning groups III, IV, and V ridges, there can be differences in the techniques required for grafting each of these classifications. The Group III ridge defect needs to be evaluated for the degree of dehiscence. When the dehiscence is small and good implant stability and bone coverage is possible, then grafting with implant placement is feasible. However, as the dehiscence increases to more than a few millimeters and especially if both buccal and palatal defects are encountered, it is prudent to consider staging treatment. Therefore, particularly in the aesthetic zone, it is necessary to perform a ridge augmentation first with implant placement at a later date. Group IV ridges have a similar concern. A buccal fenestration will be the most common in this class because the palate tends to widen apically on the palatal side. A buccal fenestration can often be managed with a bone graft at the time of implant placement. However, if the fenestration appears to be large and affects implant stability, then a staged grafting approach would be recommended instead. Group V ridges should be considered for a staged grafting approach. The ridge should first undergo a bone graft augmentation and then after healing, implant placement may be performed.

The advantages of this new RDRC include (1) more accurate evaluation of the clinical situation prior to surgery to determine treatment options based on a radiographic template as a surgical guide, (2) the ability to evaluate the need for hard tissue augmentation and to simulate the necessary augmentation prior to surgery, (3) better selection of appropriate implant type and size before surgery, and (4) provision for better communication between restorative dentists, implant surgeons, and patients concerning the treatment procedures and the expected outcomes.

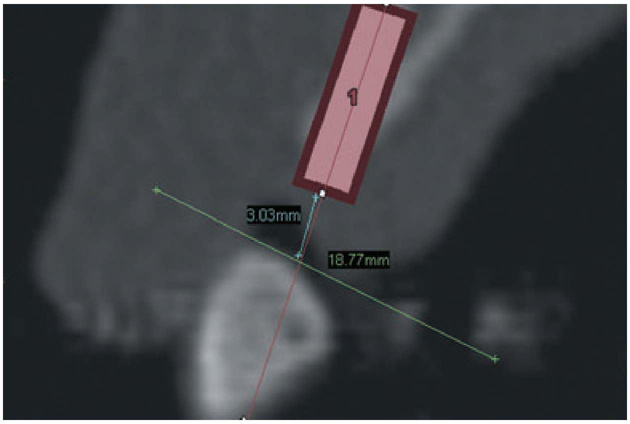

Figure 5 A Group V ridge defect: The simulation shows facial and palatal dehiscences in conjunction with a facial fenestration defect.

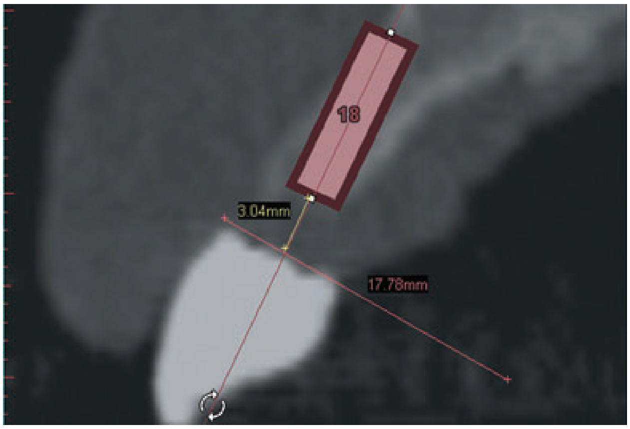

Figure 4 A Group IV ridge defect: The simulated implant perforates the apical area of the facial plate.

CONCLUSIONS

A new horizontal ridge defect categorization system (RDRC) is proposed, driven by ideal prosthetic placement instead of just ridge shape. Using the proposed new RDRC, bone defects may be identified and therefore may provide for more accurate treatment planning. The results indicate that a high number of cases in the maxillary anterior area would require augmentation procedures in order to achieve ideal implant placement and restoration.

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