Initial Stability of Two Dental Implant Systems: Influence of Buccolingual Width and Probe Orientation on Resonance Frequency Measurements

Tolga F. Tözüm, DDS, PhD;* Ilser Turkyilmaz, DDS, PhD;† Bilge Turhan Bal, DDS, PhD‡

ABSTRACT

Background: Although many factors seem to have an impact on the resonance frequency (RF) values of implants, there is a lack of evidence about some other parameters, which may have an influence on implant stability.

Purpose: The aims of the study were to determine whether initial stability of a dental implant differs when the buccolingual width of the bone changes, to determine whether different orientations affect the RF measurements in the RF device, and to investigate two dental implants with different morphologies with regard to their initial stability.

Materials and Methods: Two implant systems (Tidal Spiral Dental Implant Systems, Huntsville, AL, USA, and MIS Seven, MIS Implants Technologies Ltd., Shlomi, Israel) with diameters of 3.75 mm and 4.2 mm and with a length of 13 mm were used. Following the insertion of implants, buccolingual thinning of the models was performed in 2-mm increments ranging between 0 and 8 mm.

Results: A statistically significant decrease for implant stability quotient (ISQ) values was noticed for both diameters and both systems for all dimensional time points of the blocks ($p < .05$). The second system (more number of threads) resulted with higher ISQ values for both diameters than the first system (lower number of threads) ($p < .001$). The orientation of the probe influenced the measurements, where a standard orientation is advisable for the magnetic RF device.

Conclusion: Different implant surface geometries seem to behave in different patterns in terms of initial stability. Dimensional changes in buccolingual direction seem to have an impact on the initial stability, where wider implants also presented higher ISQ values than narrow ones.

KEY WORDS: bone loss, horizontal dimension, implant, resonance frequency analysis, stability

INTRODUCTION

Resonance frequency (RF) analysis is an objective, reliable, easily practicable, noninvasive, and nondestructive method developed for dental implantology, where it quantitates the dental implant stability.[1–5] The implant-bone interface is measured from an RF as a reaction to oscillations exerted onto the implant/bone contact, where the unit of measurement is recorded as implant stability quotient (ISQ) by using commercially available device (Osstell™, Integration Diagnostics AB, Göteborg, Sweden).[1] The stiffness can be considered in three ways: (1) the stiffness of the implant components themselves associated with the geometry and material composition, (2) the stiffness of the implant-bone interface (connection between the surface of the implant and the surrounding bone), and (3) the stiffness of the bone itself associated with the trabecular/cortical bone ratio and bone density.[6]

ISQ values recorded as initial stability measurement (intraoperative primary stability value) and posthealing

*Associate professor, Department of Periodontology, Faculty of Dentistry, Hacettepe University, Ankara, Turkey; †assistant professor, Department of Prosthodontics, University of Texas Health Science Center at San Antonio, TX, USA; ‡assistant professor, Department of Prosthodontics, Faculty of Dentistry, Gazi University, Ankara, Turkey

Reprint requests: Dr. Ilser Turkyilmaz, Department of Prosthodontics, Dental School, University of Texas, Health Science Center at San Antonio, 7703 Floyd Curl Drive, MSC 7912, San Antonio, TX 78229-3900, USA; e-mail: turkyilmaz@uthscsa.edu

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stability measurement (postoperative secondary stability value) are important when evaluating the clinical performance of dental implants.[4,6–9] As well as its previous electronic cable version (Osstell), a newer magnetic wireless RF analyzer (Osstell Mentor) is also available. The wireless magnetic device uses the ISQ as a measure, ranging from 1 to 100: A high ISQ value indicates high stability, whereas a low value indicates low implant stability. Several in vitro, animal, and clinical studies were performed by using the cable and wireless versions.[3,5,10–13] An in vitro study speculated that RF measurements calculated by the previous electronic cable version were more precise than the mobility-measuring device (Periotest®, Siemens AG, Bensheim, Germany) measurements to determine the actual implant stability at peri-implant defects.[14] Furthermore, a clinical study presented that changes in dental implant stability measured with the newer magnetic wireless RF analyzer correlated well with those found with the previous electronic RF analyzer, and both devices confirmed the initial decreases in implant stability that occurred following placement and identified an increase in stability during functional loading in human subjects.[11] An in vitro study also demonstrated that the newer magnetic wireless RF analyzer seemed to be a suitable, sensitive, and reliable device to determine dental implant stability, where it can detect circular, vertical peri-implant defects in millimeter increments ranging between 0 and 5 mm.[5] Studies with previous electronic version with cable demonstrated the importance of transducer position during measurements, and the distance of the transducer from bone and the variations in the tightening of the transducer may have an impact on the RF measurements.[1,12,15–17] As well as these parameters, implant surface, bone density, gender, age, surgical method used, and anatomic location during surgical intervention may also have an impact on the initial stability of the implant, which will affect the RF measurements.[3,13,18,19]

It is clear that implant surface geometry and surface type have an influence on primary and secondary stability of the dental implant.[20–25] Tapered implants have a higher insertion torque than cylindric implants because of a greater frictional surface, where continual machine-inserted implants had less insertion torque values than discontinual manual insertion values, and it was also stated that implant design had a great importance on the initial stability in bone.[21,23–25] To provide a precise basis for clinical applications of implant placement, where immediate placement and loading have an increasing popularity, recent studies focused on initial stability of the implants have growing interest.

Although many factors presented their importance on implant stability and RF measurements, to the authors' knowledge, there is still a lack of evidence about some other parameters, which may have an influence on dental implant stability. Thus, the aims of the present in vitro study were (1) to determine whether initial stability of a dental implant differs when the buccolingual width of the bone changes, (2) to determine whether different orientations affect the RF measurements in the newer wireless RF device, and (3) to investigate two dental implants with different morphologies with regard to their initial stability.

MATERIALS AND METHODS

Dimensional Preparation of the Acrylic Models and RF Analysis Measurements

A total of 40 tapered screw-type and internal hex connection dental implants with diameters from two different dental implant systems (first system: Tidal Spiral Dental Implant Systems, Huntsville, AL, USA; second system: MIS Seven, MIS Implants Technologies Ltd., Shlomi, Israel) of 3.75 mm ($n = 10 + 10 = 20$) and 4.2 mm ($n = 10 + 10 = 20$) and a length of 13 mm were provided to be used in the present study. Both implants used are basically tapered implants, which causes lateral compressive stresses in the bone during implant placement that turns in high primary stability. However, the MIS implants have more number of threads than the Tidal-spiral implants with the same length. In addition, the surface of MIS Seven system is dual-roughed by sand-blasting and acid-etching procedures, and their geometric design includes dual threads, three spiral channels stemming from the apex, microrings on the implants' neck, and a changing thread thickness along the implant. Tidal Spiral implants have relatively clean surface, which is achieved by "wet-shot blasting" procedure using wet aluminum oxide particles. Wet-shot blasting leaves gently round-edged prominences (hillocks) on the surface of the implant, showing an increase of rounded, "soft" microscopic prominences and no scratches, pock-marks, or fragile, sharp-edged prominences.

Ten standard transparent self-curing acrylic resin models polymerized under pressure, which eliminates the trapped air bubbles in the models, were fabricated. The dimensions of the acrylic models were standardized as buccolingual direction (horizontal): 14 mm; apico-coronal direction (vertical): 15 mm; mesiodistal direction: 25 cm. Each acrylic resin model received four implants, including both of the dental implant systems with each diameter.

Surgical drills by using a step-by-step procedure were used as indicated by both of the implant systems. To stop heating of the acrylic models, saline irrigation was used. The left side of the acrylic model received the first implant system with a diameter of 3.75 and 4.2 mm, and the right side of the model received the second implant system with a diameter of 3.75 and 4.2 mm in 10 different acrylic models (Figure 1). Dental implants were placed into the implant sockets by using torque control system (Implant MED, Type: SI-923; W&H Dentalwerk Bürmoos GmbH, Salzburg, Austria) without any dimensional changes.

Horizontal dimensional changes in terms of buccolingual direction were created by removing the resin through the whole block (from mesial to distal) equally from buccal and lingual sides. The horizontal dimensional changes (buccolingual width) were performed in 2-mm increments ranging between 0 and 8 mm to the same extent on the whole resin blocks (d0 = no defect, d2 = 1 mm from buccal + 1 mm from lingual = 2 mm, d4 = 2 mm + 2 mm = 4 mm, d6 = 3 mm + 3 mm = 6 mm, d8 = 4 mm + 4 mm = 8 mm). The horizontal dimensional changes were measured by using an electronic digital caliper (Max-Cal, MFG Co. Ltd., Tokyo, Japan) (Figure 2).

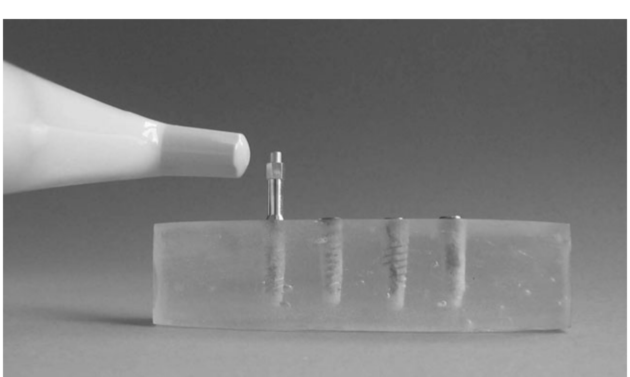

Figure 1 The probe of the wireless RF device is held in mesiodistal direction close to the peg during the measuring process. (RF = resonance frequency.)

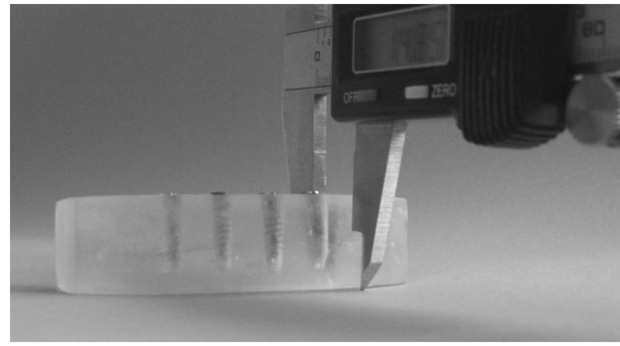

Figure 2 The digital caliper is used to measure the buccolingual width of the acrylic model during the whole trimming process.

Only one experienced periodontist performed in vitro surgical drilling, horizontal dimensional preparation, and implant insertion, and one experienced prosthodontist performed all smart peg installations and RF measurements.

RF Analysis

Following implant placement into the acrylic socket, buccolingual (horizontal) preparation of the model was carried out by carefully removing the acrylic material. After each preparation, RF measurements were performed. The rigidity of the implant-acrylic interface was assessed by the magnetic wireless RF analysis method. The RF analysis technique analyzes the RF (range 110–10,000 Hz) of a smart peg (Integration Diagnostics AB, Göteborg, Sweden: Type 27 for Tidal Spiral Dental Implant Systems and Type 32 for MIS Implants Technologies Ltd.), which can be attached to the implant system with the aid of a cylindrical plastic holder provided by the company, 4 to 5 Ncm torque was enough. The probe (Probe 2, Osstel Mentor) of wireless RF analyzer was held perpendicular to the jawline buccolingually (10 repetitions) and mesiodistally (10 repetitions). The ISQ value is presented on the screen of the analyzer. The RF values are converted to ISQ by the analyzer automatically. ISQ value ranging between 1 and 100 demonstrated that the higher the ISQ, the more stable is the dental implant.

Statistical Analysis

Statistical software (SPSS 11.0, SPSS Inc., Chicago, IL, USA) was used for statistical analysis. The Shapiro-Wilk's test was used to test the normality of distribution for the ISQ values. Mann-Whitney *U* test was used to explore the differences between ISQ values achieved (buccolingually and mesiodistally) and dimensionally changed acrylic models in both buccolingual and mesiodistal directions. A value of $p < .05$ was considered as statistically significant.

RESULTS

Influence of Horizontal Width around Implants on ISQ Values

Both implant systems presented a statistically significant decrease on ISQ values (measurements taken from buccolingual direction) for both diameters as the horizontal width was reduced ($p < .05$) (Figures 3 and 4).

Influence of Probe Orientation on ISQ Values

However, when the mesiodistal orientation of the ISQ measurements was considered, MIS implants did not present any significant difference for the whole horizontal width reduction period for 3.75 mm diameter ($p > .05$) (Figure 5). When Tidal Spiral system was evaluated from mesiodistal orientation, no significant difference was noted for 3.75 mm diameter during the whole horizontal width reduction period except from d0 to d2 ($p < .001$) (see Figure 5). For wider diameter (4.2 mm), both systems did not present any significant decrease ($p > .05$), except from d6 to d8 defect ($p < .001$) (Figure 6).

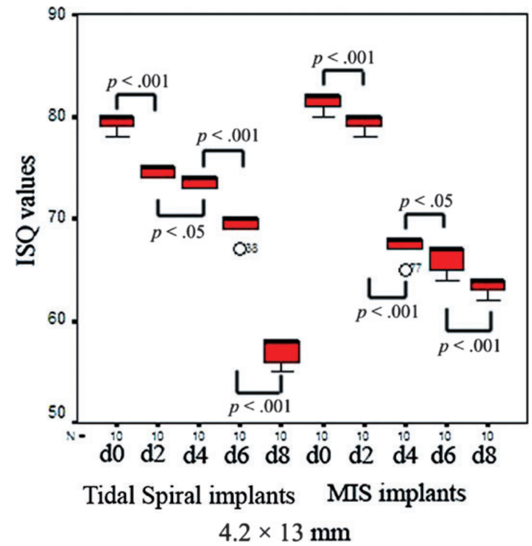

Figure 4 When ISQ measurements (4.2 × 13 mm) were taken from *buccolingual* direction and buccolingual trimming was performed, a statistically significant decrease ($p < .05$ and $p < .001$) was noted for both of the implant systems at d0, d2, d4, d6, and d8. (ISQ = implant stability quotient.)

Influence of Implant Diameter on ISQ Values

When RFA values were recorded from buccolingual (standard) position, ISQ values without any horizontal preparation (d0) were 76.6 ± 0.7 and 79.6 ± 0.7 for 3.75 mm-diameter Tidal Spiral and 4.2-diameter Tidal Spiral implants, respectively, which were statistically

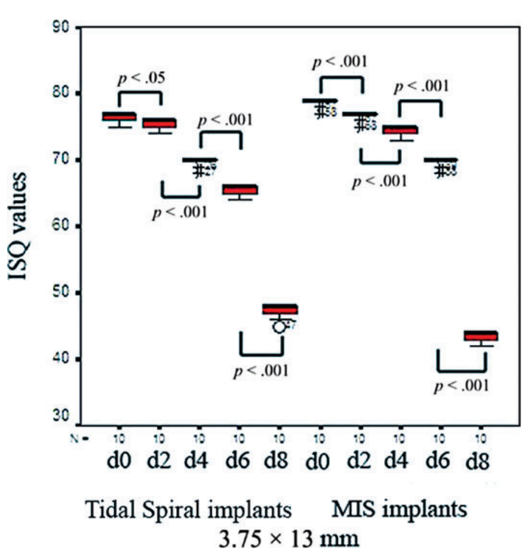

Figure 3 When ISQ measurements (3.75 × 13 mm) were taken from *buccolingual* direction and buccolingual trimming was performed, a statistically significant decrease ($p < .05$ and $p < .001$) was noted for both of the implant systems at d0 (no defect), d2 (defect 1 mm from buccal + 1 mm from lingual = 2 mm), d4, d6, and d8. (ISQ = implant stability quotient.)

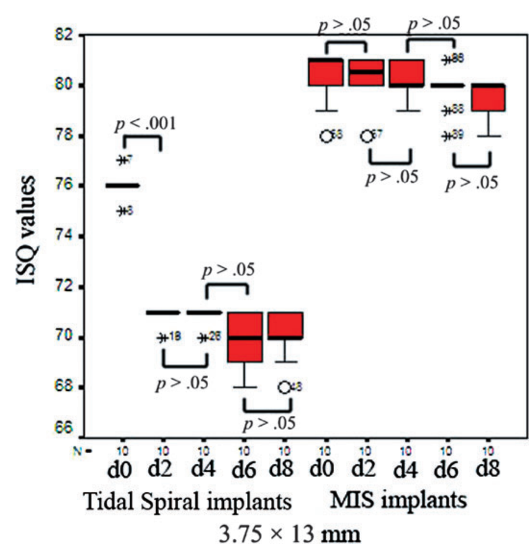

Figure 5 ISQ measurements (3.75 × 13 mm) were taken from *mesiodistal* direction. No significant differences ($p > .05$) were noticed for both systems, except Tidal Spiral (Tidal Spiral Dental Implant Systems, Huntsville, AL, USA) implants measured between d0 and d2 ($p < .001$). (ISQ = implant stability quotient.)

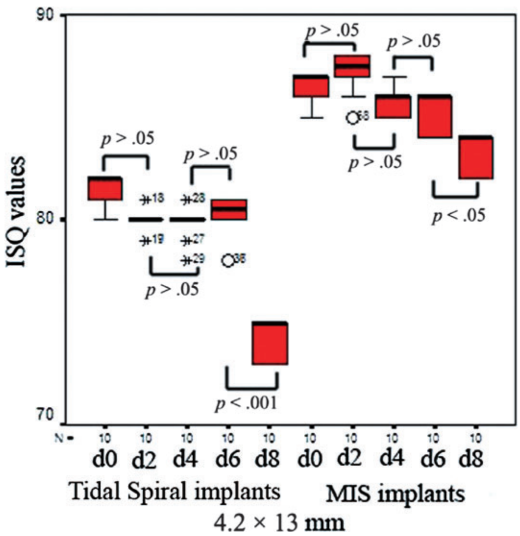

Figure 6 ISQ measurements (4.2 × 13 mm) were taken from *mesiodistal* direction. No significant differences ($p > .05$) were noticed for both systems, except a significant decrease between d6 and d8. (ISQ = implant stability quotient.)

significant ($p < .001$); while corresponding values were 78.7 ± 0.6 and 81.6 ± 0.7 for 3.75 mm-diameter MIS and 4.2 mm-diameter MIS implants, respectively, which were statistically significant ($p < .001$).

Influence of Implant Type on ISQ Values

When RFA was performed from buccolingual (standard) position, recorded ISQ values without any horizontal preparation (d0) were 76.6 ± 0.7 and 78.7 ± 0.6 for 3.75 mm-diameter Tidal Spiral and 3.75 mm-diameter MIS implants, respectively, which were statistically significant ($p < 0.001$); while corresponding values were 79.6 ± 0.7 and 81.6 ± 0.7 for 4.2 mm-diameter Tidal Spiral and 4.2 mm-diameter MIS implants, respectively, which were also statistically significant ($p < 0.001$).

DISCUSSION

When the anatomic variations are considered in clinical applications, as well as bone density, surgical technique, and implant system used, based on the findings of the present in vitro study; the width of the alveolar bone (buccolingual width) seems to be critical during the evaluation of primary stability using ISQ values. A significant decrease in ISQ values (measured from standard buccolingual position) was noted when the level of buccolingual width was lost in the present study. Performing buccolingual dimensional changes by using 2-mm increments around implants resulted with a significant implant stability loss as demonstrated with a decrease in ISQ values (measured from standard buccolingual position) for both diameters and for both dental implant systems. However, this result should be noted carefully because osseointegrated implants in vital bone may react in a different manner because of bone remodeling process. The results of the present study also demonstrated that implants with wider diameter presented a trend of higher ISQ values than narrow ones, even when the buccolingual width dimensional changes were decreased. Based on the findings of this in vitro study, it may be speculated that using implants with wide diameters may result with higher implant stability than with narrow ones, which were placed into thicker or thinner buccolingual widths.

The second aim of the study was to determine whether different orientations affect the RF measurements in the newer wireless RF device. Veltri and colleagues reported that transducer orientation influenced the ISQ values measured using the previous electronic cable version in human subjects.[12] They demonstrated that transducer orientation located in buccolingual direction or lingual-buccal direction was the same, and no difference was found between ISQ values achieved from mesiodistal and disto-mesial directions. However, lower ISQ values were found in measurements taken from mesiodistal and disto-mesial directions than from buccolingual and lingual-buccal directions.[12] A very recent in vitro study performed with human cadaver jawbone demonstrated that significantly lower ISQ values were achieved in buccolingual direction than in mesiodistal direction measured using the mobility-measuring device and the previous electronic cable RF analyzer.[26] In the present study, ISQ values demonstrated a trend of decrease in buccolingual direction compared with mesiodistal measurements for both implant systems analyzed by the new wireless magnetic RF device. A statistically significant decrease was also noted for ISQ values measured from buccolingual direction during the narrowing process of buccolingual width. Previous studies with previous cable version speculated that transducer cantilever beam with longer effective length may result in a lower RF and, thus, low ISQ.[12,26] They further stated that this phenomenon may explain the significant differences of ISQ values achieved from buccolingual and mesiodistal directions.[26] However, in the present trial, the wireless version was used without any transducer cantilevers, and, thus, the cantilever effect cannot have an impact in the present study. The present data demonstrated lower ISQ levels in buccolingual direction than in mesiodistal directions in all of the buccolingual dimensional changes, as reported by the previous cable version studies.[12,26] This might be related with the width of the buccolingual dimension, where the models were thinned. However, no efforts were performed for the mesiodistal dimension, and the ISQ values achieved from mesiodistal direction were always higher than the buccolingual values. Based on the previous evidence and the findings of this study, one may speculate that buccolingual width of the surgical area may have an influence on the primary implant stability (ie, thinner crest of the ridge in the mandible).[26] A higher value may be analyzed when stability was measured from mesiodistal direction than buccolingual direction, which seem to be related with the thickness of the alveolar ridge. Moreover, like the previous cable version, a standardized probe position for the wireless version, the buccolingual position, may be advisable during primary stability determination and secondary (bone remodeling process during the healing phase) stability.[12,26]

The third aim of the present study was to investigate two implant systems with different morphologies with regard to their initial stability. It is clear that primary stability and insertion torque values are also dependent on the system used,[20,24] and self-tapping tapered implant design brings higher initial stability than straight cylindric implant systems.[27] O'Sullivan and colleagues presented that surface geometry has a great importance, in which the design of the implant had the ability to increase the interfacial stiffness at the implant-bone interface analyzed by insertion torque and RF analysis (previous cable version).[20] We are in agreement with the previous studies that, within the limitations of the present study, it has been shown that higher insertion torque values were achieved for both implant systems.[18,20,24,27] However, although both implant types revealed higher primary stability, MIS implants had significantly higher primary stability for both diameters used in this study. This difference can be explained by different types of designs and surface characteristics of the implants. As mentioned in the "Materials and Methods" section, both implants used are basically tapered implants, which causes lateral compressive stresses in the bone during implant placement that turns in high primary stability. However, the MIS implants have more number of threads and rougher surface than the Tidal-spiral implants with the same length. When the buccolingual thickness was considered, both systems presented a decrease during the reduction of the acrylic model in 2-mm increments (12, 10, 8, and 6 mm buccolingual thickness) compared with baseline thickness (14 mm) measured from buccolingual direction. When the pattern of decrease was evaluated, wider diameter implants always presented higher ISQ values than narrow ones for both systems. However, both systems with different diameters did not present a similar pattern of decrease; there were random ISQ values during the reduction of buccolingual thickness of the model, which may indicate that each implant system results with different stability values. This value seems to be different for different systems. When the mesiodistal direction was evaluated for ISQ measurements, higher ISQ values were determined even when the buccolingual thickness was reduced for both systems. Thus, we might suggest that buccolingual direction might be suitable for the detection of primary stability compared with mesiodistal direction using the new magnetic wireless RF analyzer. It may be speculated that each surgical region should be evaluated in caution prior to implant placement, where bone width in terms of buccolingual direction seems to be critical. Thus, studies evaluating different anatomic regions as well as bone density, surgical procedure and implant system used should be analyzed carefully.

CONCLUSION

This in vitro comparative study demonstrated that wider-diameter implants have a higher stability than narrow-diameter implants, which can be measured by the wireless RF analyzer. Furthermore, orientation of the probe influences the measurements, where a standard orientation is advisable for the wireless device. Different implant surface geometries seem to have different patterns in terms of initial stability, in which it may be assumed that ISQ measurements of different systems may not be comparable. Moreover, dimensional changes in buccolingual direction seem to have an impact on the initial stability of implants, where wider implants also presented higher ISQ values than narrow ones. It may also be speculated that horizontal thickness (buccolingual width) of alveolar bone seems to be critical for the initial stability of dental implants. It should be kept in mind that, because this is an in vitro study performed on the acrylic resin blocks, which has a different expansion coefficient compared with a living bone, during implant placement, the results of this study may not literally reflect the clinical situation.

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