DOI: 10.21608/ADJALEXU.2020.45441.1112

EVALUATION OF BONE WIDTH CHANGE USING A TWO-STAGE RIDGE SPLITTING APRROACH in NARROW POSTERIOR MANDIBULAR RIDGE (AN OBSERVATIONAL CASE-SERIES STUDY)

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ABSTRACT

INTRODUCTION: Alveolar ridge splitting technique is a commonly used procedure for horizontal ridge augmentation of narrow ridges to allow placement of implants. However, the conventional one stage technique might randomly cause mal-fracture and necrosis of the fractured part in case the periosteum is detached from the distracted bone-plate.

OBJECTIVE: to evaluate the effectiveness of the two-stage ridge splitting technique to preserve the blood supply and avoid necrosis of the expanded part.

MATERIALS AND METHODS: Twelve patients were selected randomly presenting a posterior mandibular narrow ridge of less than 3 mm width. The sample was selected to match a list of inclusion and exclusion criteria. In the first stage, all patients underwent mandibular ridge splitting technique using piezotome. In the second stage, ridge expansion and implants were placed with only envelope flap. Assessment included measurement of bone dimensions and gain of bone width from the cone beam computed tomography.

RESULTS: There was significant bone gain after the bone expansion measured at 2 weeks followed by some bone resorption at 4 months after implant placement. The bone density was increased at 4 months by average two times compared to the initial measurements in all patients. There was a significant increase between the primary implant stability at time of implant placement and 4 months after implant placement in all patients. All cases showed uneventful healing, except two cases, of which one showed soft tissue dehiscence and the other showed soft tissue infection. Both cases were managed conservatively.

CONCLUSION: This study showed the staged ridge splitting approach to be safe and predictable therapy that might overcome possible complications of one-stage ridge-split procedures.

KEYWORDS: Narrow mandibular ridge, Horizontal ridge augmentation, Ridge splitting, piezosurgery.

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INTRODUCTION

After tooth extraction, great changes occur to the alveolar ridge dimensions. It has been found that, severe resorption in the alveolar ridge width occurs reaching up to 50%. This loss, which equals to 5-7 mm, occurs mainly in the first three months after extraction. The volume reduction of the alveolar bone may interfere with proper implant placement and affect the fabrication of proper functional and esthetic fixed or removable dentures. (1)

In order to restore edentulous areas with dental implants, at least 1-1.5 mm of buccal and lingual / palatal bone should surround the implant. (2) Thus, different techniques are being used for ridge augmentation including: Guided Bone Regeneration (GBR) using membranes in combination with different bone materials, (3), autogenous bone blocks harvested intra or extra orally, (4), or distraction osteogenesis (5). All of the previous treatment modalities have risks of dehiscence, infection and long treatment time (4).

To overcome the drawbacks of these augmentation techniques, Tatum (6) introduced an approach to augment the narrow ridges, described as alveolar ridge expansion using hand osteotomes with gradually increasing sizes. Another approach was defined as Alveolar Ridge Splitting, introduced by Simion et al (7) and includes longitudinal splitting of the alveolar ridge into two parts using small chisels. Both approaches were recommended in soft bone quality and allow simultaneous implant placement in one stage. (8)

However, with dense bone quality, as in the mandible, there is a risk of uncontrolled fracture and avascular necrosis of the laterally positioned buccal segment in case the procedure is not carried out flapless with no detachment of periosteum from the distracted bone plate. (9) This is because of the lower flexibility and thicker cortical plates. (10) Therefore, an approach was introduced by Scarano et al (11) which involves splitting and expansion of the atrophic mandible in two stages by ultrasonic piezotome. This technique has the advantage of avoiding

necrosis if mal-fracture occurs after ridge splitting. The Staged Ridge Splitting (SRS) had shown to have a success rate of 96.88% and a mean increase in the width of the ridge of 5.17 +/- 0.86mm.

The corticotomies can be done by either micro-saw devices [9], or piezoelectric devices [9,12,33]. The piezoelectric devices have the advantage of controlled and precise cutting of the hard alveolar bone, and thus avoiding mal-fracture of the osteomized segment. Moreover, their use prevents injury to soft tissue such as nerves, blood vessels or the schneiderian membrane, and thus allow for good visibility of the surgical field and less postoperative complications. [13]

Therefore, the aim of this study was to evaluate the change in bone width using a two-stage alveolar ridge splitting technique using piezoelectric device with simultaneous implant placement in order to treat narrow posterior mandibular ridges avoiding the risks of mal-fracture and necrosis of the split part.

MATERIALS AND METHODS

1. Study Design

This prospective study was conducted between May 2018 and December 2019 on twelve patients in need for implant placement for their narrow posterior mandibular missing space.

All patients were selected from the outpatient Clinic of Oral and Maxillofacial Surgery Department, Faculty of Dentistry, Alexandria University.

2. Criteria for patient selection

Inclusion criteria

Adult patients aged 18-60 years old with no gender predilection.

Patients presenting with posterior mandibular (premolar-molar area) narrow alveolar ridge that requires dental implantation.

Minimum bone width of 3 mm

Minimum bone height of 10 mm

Proper inter-occlusal space

Exclusion criteria

Uncontrolled diabetes.

Heavy smokers.

Current chemotherapy or radiotherapy.

Alcohol or drug abuse.

Pregnant women.

Active infection.

Inter-occlusal space not less than 7-8 mm.

Parafunctional habits.

Informed consent

All patients were informed about the procedure that was performed and each participant signed a written consent prior to being enrolled in the study. It was also mentioned that the patient had the right of withdrawal from the study anytime without any consequences.

Ethical approval for this study was obtained from the research ethics committee, Faculty of Dentistry, Alexandria University before beginning the study.

3. Materials

A-Piezotome

Crestal Split(CS1) tip will be used with thickness of 0.55mm and tip length of 8mm.

B-Bone spreaders

The Ridge Spreader has 3 diameters, which are 2.4, 3.2, 3.6mm, able to insert till implant of 4.5mm diameter.

C-Implant system

Tapered implant design with conical hex connection. Variable sizes available (diameters: 3.6,4.0,4.5,5.0,5.8mm – lengths: 7,8,10,12mm).

4. Methods

I. Pre-surgical assessment

1- Patient assessment

Detailed history taking, intra-oral and extra-oral clinical examination were performed. A thorough assessment of general health status was conducted to ensure that the patient could withstand a surgery under local anaesthesia.

2- Radiographic examination

A cone beam computed tomography (CBCT) was done for initial examination to evaluate bone quality, width and height at the surgical site, and to ensure that they meet the inclusion criteria. The initial bone width was recorded as BW0.

II- Surgical phase [15] (Fig. 1)

This technique was divided into two surgeries.

Before each surgery, the patient rinsed with 0.12% chlorhexidine mouth wash for 1 minute.

Inferior alveolar, lingual and buccal nerves were blocked for pain control using 4% articaine (1:100000 epinephrine).

A para-crestal incision followed by two vertical releasing incisions were done using a number 15 blade.

A full muco-periosteal flap was raised using sharp periosteal elevator to expose the bone crestally and buccally.

A trapezoidal bone block was designed by crestal, 2 vertical and basal corticotomies using a flat ultrasonic chisel.

The crestal corticotomy ended 1 mm proximal to the adjacent tooth/teeth.

All corticotomies penetrated the cortical bone and reached the cancellous bone.

The wound was closed using 3/0 simple interrupted silk sutures which were removed 10 days post-operatively.

Four weeks later, after revascularization between the bone block and the mucoperiosteum, the second surgery was performed.

A crestal incision was done to expose the crestal corticotomy and the envelope flap slightly elevated to preserve the blood supply.

The segmented bone was slightly mobilized and separated using a small chisel.

The implant site was drilled first using a lance drill to determine the osteotomy position and, then continued using the expanders in the sequence recommended by the manufacturer.

The final drilling was done using the final drill according to the size of the implant to be placed and a cover screw was secured to the implant.

Implant primary stability was tested using Osstell

Tension free suturing of the mucosa was done using 3/0 simple interrupted silk sutures

II- Post surgical phase

A-Wound healing

On the second day of each surgery, the sutured wound was examined for any signs and symptoms of infection including inflammation, redness, hotness, swelling and pus discharge.
Sutures were removed 10 days post-operatively
B-Post-operative care
Patients were instructed to apply cryotherapy extraorally at the surgical region immediately after surgery and for 24 hours, followed by hot fomentation for the next 24 hours. Oral hygiene measures were instructed to be followed Oral hygiene measures were instructed to be followed.
Antibiotic was given every 12 hours for 7 days (Amoxicillin + Clavulanic acid 1 gm)
Non-steroidal Anti-inflammatory drugs every 8 hours for 4 days (Diclofenac potassium 50 mg).
0.12% chlorhexidine mouth wash twice daily for 2 weeks
C-Radiographic evaluation [16] (Fig. 2)

The width of the alveolar bone was measured again using CBCT taken 1 week after ridge expansion and implants placement (BW1), and 4 months postoperatively (BW2).
Using BW0 measurements taken preoperatively, the initial bone width was calculated.

The amount of initial bone expansion 2 weeks after surgery was calculated (BW1 – BW0).
The amount of final bone gain was also calculated (BW2 – BW0).
The difference between the initial and final bone gain (BW2 – BW1) demonstrated the amount of bone resorption within the 4-months healing period.
Bone density (BD) was also measured 4 months after surgery.
All CBCT scans were taken in the same radiology center using the same device to minimize any errors.
D-Prosthetic work
After 4 months, healing abutments were placed in order to acquire the emergence profile.
Impressions were taken and prosthesis delivered later on.
Statistical analysis

Data were fed to the computer and analyzed using IBM SPSS software package version 20.0 (11) (Armonk, NY: IBM Corp). Quantitative data were described using range, mean, standard deviation and median. The distribution of quantitative variables was tested for normality using Kolmogorov-Smirnov test. The paired t- test was used to compare between two periods showing normally distributed quantitative variables, while the ANOVA with repeated measures was used to compare between more than two periods or stages, and Bonferroni Post Hoc test. The Friedman test was used for abnormally distributed quantitative variables, with Dunn's Post Hoc Test. Significance of the obtained results was judged at the 5% level.

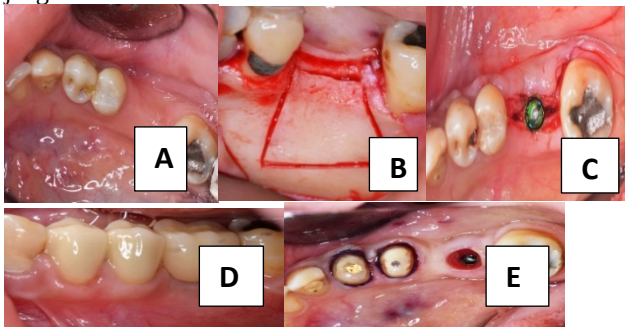

Figure 1 (A) Preoperative view. (B) Stage 1 showing the trapezoidal bone block design. (C) Stage 2 showing the implant in place in between buccal and lingual cortical plates. (D) Soft tissue emergence profile 4 months after implant placement ready for impression. (E) Final crown in place.

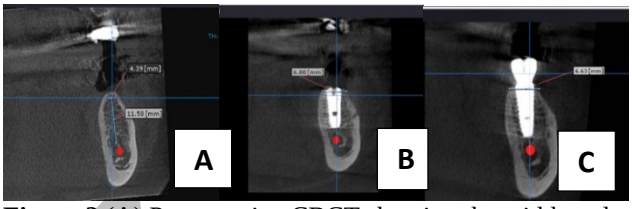

Figure 2 (A) Preoperative CBCT showing the width and length of bone. (B) CBCT immediately after implant placement. (C) CBCT 4 months after implant placement.

RESULTS

In this prospective study, twelve patients with narrow posterior mandibular ridge were planned to receive implants using a Two Stage Ridge Splitting technique.
Bone Width

There was a significant final bone gain with a mean bone width change of 2.43 ± 0.75 mm. (Table 1) (Fig. 3).
Bone density
There was a significant increase of bone density which was approximately double the initial measurement after 4 months period. (Table 2) (Fig. 4)
Implant stability

There was a significant increase between the primary stability at time of implant placement and 4 months after implant placement in all patients. (Table 3) (Fig. 5)
All cases showed uneventful healing, except two cases: one showed soft tissue dehiscence and the other showed soft tissue infection. Both cases were managed conservatively and evaluation was continued.

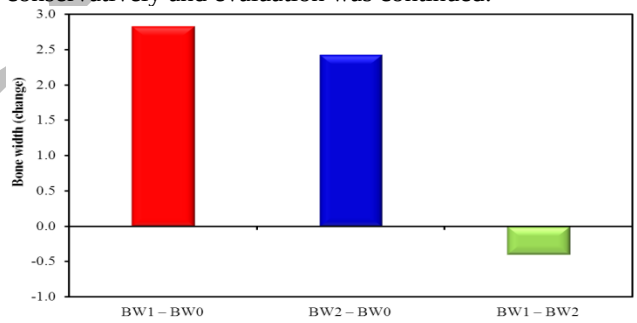

Figure (3): Comparison between the three studied periods according to change bone width (n = 12)

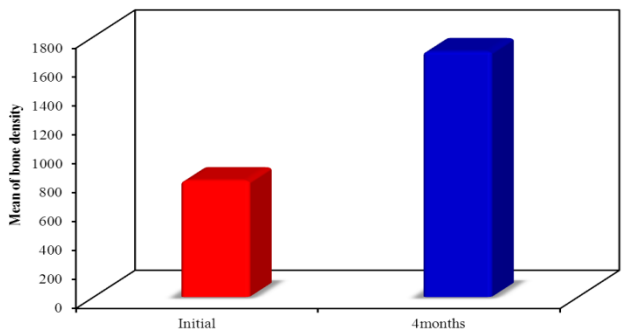

Figure (4): Comparison between the two studied periods according to bone density (n = 12)

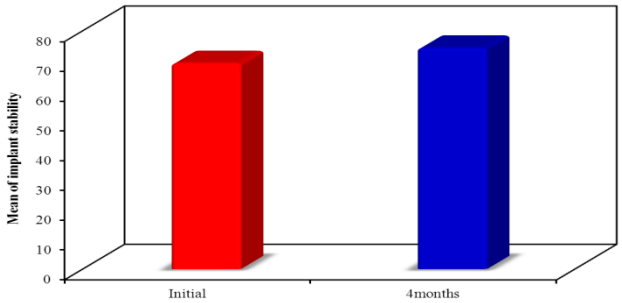

Figure (5): Comparison between the two studied periods according to implant stability (n = 12)

Table (1): Comparison between the three studied periods according to the change of bone width (n = 12)

Bone width (Change)	BW1 – BW0	BW2 – BW0	BW1 – BW2
Min. – Max. Mean ± SD. Median (IQR)	2.0 –4.70 ↑2.83 ± 0.69 2.65	1.70 – 4.40 ↑2.43 ± 0.75 2.30	0.20 –0.70 ↓0.40 ± 0.15 0.40

BW1 – BW0 : Initial bone expansion
BW2 – BW0 : Final bone gain
BW1 – BW2 : Amount of bone resorption

Table (2): Comparison between the two studied periods according to bone density (n = 12)

Bone density	Initial	4months	t	p
Min. – Max. Mean ± SD. Median (IQR)	352.0 – 1130.0 804.0 ± 279.1 920.0(540.5 –1025.5)	1420.0 – 2052.0 1697.1 ± 212.7 1704.5(1503.5 –1834.0)	14.9	<0.001*

t: Paired t-test
p: p value for comparing between the studied periods
*: Statistically significant at $p \leq 0.05$
Initial bone density measured in Hounsfield units (HU)
Bone density 4 months after implant placement

Table (3): Comparison between the two studied periods according to implant stability (n = 12)

Implant stability	Initial	4months	t	p
Min. – Max . Mean ± SD. Median (IQR)	52.0 –83.0 69.08 ± 9.61 68.50(64.5 –77.0)	56.0 – 89.0 74.25 ± 10.45 75.0(67.5 –82.0)	10.5	<0.001*

t: Paired t-test
p: p value for comparing between the studied periods
*: Statistically significant at $p \leq 0.05$
Initial implant stability measured in Implant Stability Quotient(ISQ) Implant stability 4 months after implant placement

DISCUSSION

Loss of edentulous alveolar ridge width following might cause major obstacles to reconstruct these areas and perform a proper dental implant insertion. [17] To allow the use of a regular implant platform, the need for bone expansion was met either using lateral or interposition horizontal bone augmentation, ridge splitting and gradual expansion (distraction osteogenesis) or ridge splitting and spontaneous expansion. [18]

This study evaluated the performance of the delayed expansion technique for the rehabilitation of the posterior mandibular atrophic narrow ridge with emphasis on the radiographic representation and implant stability. The study reported 12 cases of atrophic edentulous posterior mandible that need dental rehabilitation and where 12 implants were placed.

This study chose to include the posterior area of the mandible, premolar-molar area. This was an apparent choice owing to the natural difference in width between the anterior and the posterior areas, which would have induced inaccuracy in the measurements of the presurgical, after splitting and postsurgical bone width. Furthermore, the difference of bone density and histologic bone-morphology between the mandible and the maxilla influence the approach used in the bone splitting technique. In all of the cases in this study, the ridge splitting was performed using vertical crestal osteotomies. [15] This was because the posterior mandible is mostly made up of dense compact bone with high risk of bone plate fracture during distraction from a single crestal osteotomy.

This is not the case in the maxilla where the mostly cancellous architecture and the lower density of bone will only require a crestal osteotomy for the splitting to be performed without the need for vertical osteotomies in cases where 1- or 2-mm width gain is required. None of the cases in this study revealed bone fracture or inability to place the implant in the secondary operation. This comes in agreement with Enislidis et al and Scarano et al, emphasizing the main advantage of the two staged technique and the safer easier surgical procedure during bone expansion and implant placement, provided a surgical technique is used with raising full thickness flaps. Contrary this is not the case if Flapless Piezotome-Crest-Split is used in a single stage procedure. [9]

In this study, the piezoelectric device was used to perform the corticotomies. This owes to its advantages over the conventional bone cutting methods, which include highly precise cutting without pressure and safety to the adjacent soft tissues and vital structures, as well as it´s bone-lossless cutting performance. This was supported by Bassetti et al and Scarano et al, who both used the piezo electric surgery device, clarifying its advantages and producing no complications in their studies. [11,31]

All of the cases demonstrated normal soft tissue healing during both stages of the surgery, except 2 cases where abnormal healing was observed. One case reported dehiscence following the second surgery. It was postulated

that this inconvenience was due to the sharp edges of the expanded buccal plate causing soft tissue laceration during healing. This was managed later on with the other cases by smoothening the sharp bony edges. No dehiscence case was reported by Scarano et al in their study about delayed ridge splitting. However; it a common complication reported in the conventional splitting technique, with varying ideas to overcome it either using membrane, contouring grafting material, PRF, or even autogenous connective tissue graft, and highly depends on the metric extent of distraction. [11,19-21]

Another case reported minor soft tissue infection after the corticotomy first surgery. That was because the patient did not follow proper oral hygiene procedures after the surgery and cannot be considered a specific complication of the presented surgical technique but a common event in any intraoral surgical procedure.

During ridge expansion and implant placement in the second surgery, none of the cases showed bone dehiscence defects or fenestration. Complications at implant placement such as fenestration and dehiscence based on anatomical contour differences are avoidable events provided a self-evidently correct planning of the surgery was performed based on precise clinical examination and radiographic diagnosis. [23]

Implant stability was assessed using Osstell in all patients immediately after implant placement to give a quantitative value for the primary implant stability. All of the implants showed good primary stability. The mean initial ISQ value was 69.08 ± 9.61. These high recorded values are known in the literature to be an indicative for a primary or secondary surgical protocol and an early loading restorative protocol, even though in this study we used delayed loading protocol. [24] Similar encouraging primary stability outcome was reported by Scarano et al [11] while utilizing the staged splitting approach as well as it was reported for the single stage Flapless Piezotome Crest Split [9]. The occurrence of abundant apical bone with sufficient quality is a mandatory prerequisite for any ridge splitting technique, as it's the main source of implant primary stability. This may explain the similar results reported by different utilized splitting techniques, either simultaneous, delayed or staged/ gradual. [25] Despite the fact that a high ISQ value was obtained in the initial measurement, this study opted for a two-stage implant placement technique with a four months healing period before the start of the prosthetic phase.

Upon re-entry to start the prosthetic phase, implant stability was measured to obtain a numerical value that represent the secondary stability of the implant and the commencement of the remodeling phase during implant healing, representing osseointegration occurrence. The mean calculated secondary stability value was 74.25 ± 10.45. This reported value showed a statistically significant increase from the initial value (p <0.001). These values came to put a quantitative value to the fact that all of the twelve implants in this study were successful and proceeded to the prosthetic loading with fixed restoration. Similar outcome was reported by Abu Tair [22] , despite reporting minor complications. On the other hand, Scarano et al [11] reported a 96.88% implant success rate, utilizing the two staged ridge splitting protocol, where upon re-entry two implants had to be removed.

As long as apical implant fixation and primary stability occurs; the subsequent osseointegration won't be influenced by the splitting technique utilized or the grafting technique performed. Accordingly; secondary implant stability and osseointegration is not a valid judging criterion for the success of the splitting technique. Failure to attain osseointegration and loading the implant may be attributed to the case selection processes in the first place, where splitting of a thin buccal plate fragment with insufficient apical bone width will create a thin buccal bone flap deprived from both buccal and endosteal blood supply provided a full thickness mucoperiosteal flap is raised. This is not case with the flapless approach. [9,27]
Crestal bone width was measured preoperatively, 2 weeks after expansion at the time of implant placement, and 4 months later on. The study reported a statistically significate gain 2 weeks after expansion by 2.83 ± 0.69 mm (p< 0.01). The width was also measured after four months at the time of the implant restoration phase, and reported a final bone width gain of 2.43 ± 0.75 mm. The final width showed a statistically significate decrease, by 0.40 ± 0.15 mm, when compared to the initial bone expansion measured immediately after implant placement (p< 0.01).

A comparable mean gain in crestal bone width values were reported by Abu Tair [22] , 3.22 ± 0.97 mm, and Li et al [15] , 2.37 ± 1.44mm. On the other hand, Scarano [11] reported a mean gain in crestal bone width of 5.17 ± 0.86 mm. A significant gain in the crestal bone width is a logical finding, as it is the basic outcome intended from the ridge splitting blueprint, with any technique used. Therefore, the method to ascertain alveolar width expansion success is not by implant success, but by marginal bone dimensional stability. This is in accordance to Albrektsson and Isidor, who state that an implant is considered successful if the marginal bone loss within the first year after loading is 1.5 mm or less and during the following years, no more than 0.2 mm bone loss occurs annually. [32]

The reported 0.40 ± 0.15 mm early implant bone loss in this study is comparable with the 0.5 mm bone resorption reported by Gurler et al [28] A normal early implant bone loss is a mundane finding following implantation owing to several factors as surgical trauma, establishment of biologic width, presence of a micro gap, peri-implantitis, occlusal overload, and implant crest module. [29]

A nearly double fold increase in the bone density value when comparing the four months' postoperative value with the preoperative estimates reporting a highly statistically significant difference. The reported values in this study were in accordance with those by Mustafa et al. [30]

The mean bone density is one of the utensils used to indicate a proper bone healing and a sufficient osseointegration occurrence. The delayed ridge splitting allowed a predictable and safer increase in crestal bone width without compromise of the vascular supply of the bone flap and with no necrosis after implant placement and

during bone healing comparable to the single stage Flapless Piezotome Crest Split [9]

Although the staged splitting approach is not as simultaneous as the single stage splitting and requires a secondary operation, the time required for the delayed expansion technique did not exceed any other augmentation procedures while at the same time provides a more predictable outcome with less patient morbidity obtained with this approach comparable to the single stage Flapless Piezotome Crest Split (9)

This study demonstrated a favorable outcome of the staged ridge splitting and expansion approach in the rehabilitation of atrophic narrow edentulous posterior mandible area. The clinical and radiographic outcomes can declare that this is a safe and predictable approach in widening a horizontally narrow alveolar crest which might help to overcome the conventional splitting complications when a full mucoperiosteal flaps are raised and prevent resorption and fracture of the buccal plate, while at the same time avoid causing significant delay in the rehabilitation period. Further long-term studies with larger sample size are recommended in order to validate the attained outcomes.

CONCLUSIONS

Within the limits of this study, this study demonstrated a favorable outcome of the staged ridge splitting and expansion approach in the rehabilitation of atrophic narrow edentulous posterior mandible area. The clinical and radiographic outcomes can declare that this is a safe and predictable ridge splitting approach provided a full mucoperiosteal flaps will be raised.

CONFLICT OF INTERSET

The authors declare that they have no conflict of interest.

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