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RESEARCH ARTICLE

Use of a Biphasic Calcium Sulphate Graft to Treat Posterior Maxillary Atrophies by Avoiding a Lateral Sinus Approach

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Abstract

Augmentation of the maxillary sinus when severe atrophy and/or pneumatization of the sinus has occurred results in minimal crestal height that will not allow simultaneous implant placement has been a clinical challenge. The lateral sinus augmentation approach has been traditionally utilized in these clinical situations, but there are known complications such as membrane tears and increased post-operative issues that follow use of this technique. This article aims to propose a new technique utilizing specific surgical instruments, making it possible to increase the height of the crestal bone under the maxillary sinus in cases of significant atrophy, without complications using a two-stage crestal approach with a bi-phasic calcium sulphate as the graft material. The article will discuss the technique, present a case example and review 51 cases representing initially 1-3 mm sub sinus crestal bone heights that the technique was utilized with.

Keywords: Atrophic maxillary sinus, lateral sinus augmentation, crestal sinus augmentation, Summer's lift, bi-phasic calcium sulphate

Introduction:

Extraction of posterior maxillary teeth without implant placement in the short term allows pneumatization of the maxillary sinus to advance related to atrophy of the bone at the crest. This is complicated when periodontal disease was involved in failure of the natural teeth often resulting in progressive loss of crestal height over time. Poor quality of bone inferior to the floor of the maxillary sinus, is cancellous in nature and of type 3 or 4 density, which is associated with vertical and horizontal bone resorption post extraction often making implant placement difficult due to insufficient bone volume to house the implants. To overcome those anatomical and histological complications to implant placement, sinus augmentation is frequently required to improve the bone volume to allow implant placement.

The lateral sinus augmentation approach was introduced in 1976 by Hilt Tatum to correct crestal height deficiencies that prevented implant placement. This was initially reported by Boyne and James in 1980[1] and was utilized in maxillary atrophy cases where less then 4mm of crestal height was present. The procedure consisted of flap elevation to the zygomatic process and creation of a lateral window with subsequent elevation of the Schneiderian membrane and placement of an osseous graft material between the elevated sinus membrane and the floor of the sinus. When at least 4mm of crestal height was present simultaneous implant placement could be performed as implant initial stability was possible allowing the implants and sinus augmentation to heal together shortening treatment time till the prosthetic phase could be initiated. Shorter crestal height, thus a lack of initial stability of the implants required a phased surgical approach with sinus augmentation followed by a healing period of 4-6 months, then implant placement and another healing period of 4-6 months before restoration could be initiated.

In 1994, Summers innovated a less invasive technique using osteotomes allowing an increase in crestal height via a crestal approach[2]. This technique typically allows a gain in height of about 5mm when single sites are treated and slightly more with adjacent sites that are undergoing crestal sinus augmentation. Thus, a minimal crestal height pretreatment is 4mm for this technique. The crestal sinus augmentation approach is less traumatic to the patient with less post-operative complications (swelling and pain) related to the less extensive flap required for the technique.

Whichever technique is utilized, simultaneous implant placement allows the implant to aid in tenting the sinus membrane apically preventing crestal settling of the graft material with its loss in crestal height during healing and maturation. As the graft materials typically placed, allograft and xenograft have the potential to reduce in volume during healing. When implants are not placed at the same surgery, elevation of the sinus would require greater height then the planned implant length to placed at a subsequent surgery to accommodate for loss of height of the graft when healing had completed.

Although the two techniques for increasing the crestal height of the maxilla have different

indications, the comparison of the possible complications of those two sinus augmentation methods are different[3]. Perforation of the sinus membrane during the surgical process is the most common potential complication. The Summer's approach has been reported to have up to a 22% perforation rate[4]. Whereas the lateral window approach has been reported to have up to 58.2% and as high as a 70.8% sinus membrane perforation complication rate[5-7]. Frequently, when the membrane is torn during the lateral sinus approach it is large and graft placement has to be aborted as it requires an intact membrane to contain the graft material and prevent disbursement in the non-elevated sinus. If the tear is small, it is possible to place a resorbable membrane over the tear or suture the tear to allow graft containment and the procedure can proceed[8]. With the Summer's approach, a small tear can often be managed by placement of a resorbable membrane into the osteotomy crestally prior to graft placement. However, when the tear is large the procedure often needs to be aborted and postponed for 4-6 months, allowing the membrane to heal which is then followed by repeating the procedure by a crestal or lateral approach.

Additionally, the risks of hemorrhage associated with the posterior-anterior alveolar artery and sinusitis which have been often reported with the lateral approach are almost non-existent with the Summer's technique due to the less extensive flap elevation that is required with this technique[10,11]. A 63% artery involvement[12] and 22% sinusitis occurs[13] have been reported complication rates associated with the lateral approach. Thus, in order to avoid any major complications, the less invasive crestal (Summer's) technique is preferred when applicable.

So, the question remains, how to perform sinus augmentation when less then 4mm of crestal height is present without utilizing a lateral sinus approach? As previously discussed, osseous graft materials are particulate in nature and have the potential to disburse within the sinus or spread laterally hampering the height planned for the sinus augmentation. Combining the particulate osseous graft material with autogenous blood concentrates (PRP, PRF, or CGF) to form what has been referred to as "gummy bone" or "sticky bone" will aid in keeping the graft material from disbursing in the sinus but this does not prevent lateral spread of the graft material[14]. During respiration, internal pressure in the sinus presses crestally. So that in the absence of implants placed at the time of augmentation to tent the sinus membrane and limit pressure on the graft the graft spreads laterally decreasing the desired crestal height. This becomes a challenge in those clinical situations when there is less then 4mm of crestal height and implants cannot be placed simultaneously with the sinus augmentation.

Advances in development in the engineering of osseous grafting materials, with the advent of two-phase (biphasic) calcium sulphate with a hydroxyapatite component provides a solution to this common clinical problem. Calcium sulphate has been documented to have osteo-conductive, and bioactive properties that is well tolerated by the body

without causing inflammatory issues during healing. This material was initially proposed in 1892 by Dressman as a bone filling material[15]. Peltier in 1957 confirmed the excellent osteoconductive properties of calcium sulfate already widely used as a bone filling material in orthopedic surgery[16]. In 2000, the Italian school in collaboration with the American school, confirmed excellent results obtained by this material in oral surgery[17]. The properties of stimulating angiogenesis, activating osteoblast differentiation, its conversion to host bone and regeneration of the defect it's placed into have been reported[18]. In 2010, a modification of the phases of calcium sulphate was made by transforming it into a bi-phasic material, and in 2012 the addition of hydroxyapatite (HA) in a controlled particle size distribution, slowed down the materials resorption time allowing conversion to host bone[19]. The material after setting becomes a hard cement, sticking to the boney walls of the defect while maintaining its place during healing and maturation. Additionally, it has qualities as a barrier preventing invagination of epithelial-connective cells, thus eliminating the need for a membrane under the soft tissue during healing. Histological analysis has found that already after 3-6 months (volume dependent) 90% of the material has been replaced with host bone (immature) with less than 10% particles of the HA remaining that will eventually also be replaced by host bone[20,21].

Those properties together with the described techniques and tools as will be described allow for enlargement of the crestal width and height by a crestal sinus approach in a safe and predictable manner. Additionally, in clinical situations when the remaining crestal height is 1-4 mm where traditionally that would be treated with a lateral sinus approach, this technique may be utilized to increase crestal height, but as discussed without simultaneous implant placement. It is important to emphasize that in similar situations where we have less than 4 mm of crestal bone height with the lateral sinus augmentation technique placement of implants simultaneously would not be possible due to a lack of initial stability of the implants. Utilization of the bi-phasic calcium sulphate (Bond Apatite, Augma Biomaterials, Spotswood, NJ) with the crestal approach, due to the graft materials characteristics and its complete transformation into native host bone tents the sinus membrane and at the same time reconstructs and consolidates the height of the crest allowing avoidance of the complications associated with lateral sinus augmentation. Clinically, when minimal crestal height is present (1-4 mm) the sinus will be augmented crestally to gain an average of 5mm of total height then following healing at implant placement additional crestal height gain will be performed in a "Summer's technique" by further grafting to allow a standard-length implant to be placed and encased within bone following implant healing. Lately different surgical approaches with various techniques for augmenting when minimal sub sinus crestal height is present have been suggested. However, the surgical skill and experience of the clinicians were described as a crucial factor in the success of those procedures.

The following proposed staged crestal approach when the sub sinus crestal height is between 1 and 3 mm is termed the "Baranes technique" after the lead author of this article who developed the technique and tools. The "Baranes technique" is intended to simplify the procedure make it safer, more predictable and accessible for most clinicians, less dependent of their surgical experience and skill level. This article will introduce the technique protocols, healing sequence and the results of 51 clinical cases. Wherein, the technique and the surgical instruments contain innovative diamond burs specifically designed for initiation of the crestal osteotomy, and modified osteotomes in the kit (Augmalift™ Augma Biomaterials Spotswood NJ). Bond apatite® was utilized as the sole graft material and will be discussed. A case example will review the staged technique for a maxillary sinus with 1-3 mm of crestal height and the protocol utilized to allow the augmentation of that crest height to allow primary stability of the implant placement at a subsequent surgical appointment by "Summer's technique".

Baranes technique tools and protocol description

To utilize this technique some new innovative specific diamond burs have been designed and some old instruments known in the industry have been modified or used as is. This technique enables the clinician to perform an intra-crestal sinus lift more safely and predictably without the risk of perforating the sinus membrane during the osteotomy and the lifting of the membrane.

In cases when the bony crest height is 1 to 3 mm the procedure is done in two stages, in which during the first stage the sinus is augmented to reach 5-6 mm without placement of the implant and left to heal for 4-6 months until bone consolidation is achieved. During the second stage when the bony crest level is above 4 mm, the sinus is augmented again with a "Summer's technique" to achieve 10 mm or greater height with simultaneous implant placement and allowed to heal prior to initiation of the prosthetic phase of treatment. The kit is designed to perform the procedure in a situation of which the existing crestal height level below the sinus is 1 to 3 mm while the second stage after healing and bone consolidation when the existing crestal height is more than 4 mm, a "Summers technique" may be used with simultaneous implant placement performed. The kit is comprised of 4 diamond burs specifically designed with fixed stopers from 1-4 mm, two osteotomes with dynamic stoppers starting from a zero level, a dish to hold the graft material, and a bone carrier. (Figure 1) The diamond burs in the surgical kit were designed by Dr. David Baranes and Dr. Amos Yahav. These are a set of diamond burs of 4 mm diameter with cylindrical active part and a concave end, with fixed stoppers on each from 1 to 4 mm. The concave head and stoppers were designed to assure safe and predictable penetration through the crestal aspect of the bone until it reaches the sinus membrane without the risk of perforating or tearing the membrane. Those diamond burs are patent pending and named after the initials of the inventors "B.Y".

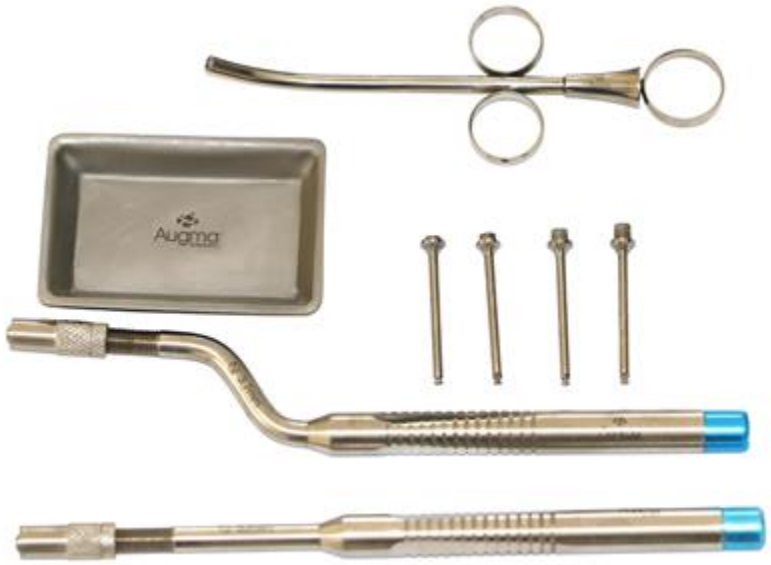

Figure 1: The B.Y. (Baranes Yahav) crestal augmentation surgical kit with osteotomes, sterile dish, crestal burs of different depths and the sinus graft syringe.

The length of the exposed active portion of the diamond burs are described by numbers from 1 to 4 correlating to the millimeters of the length of exposed active portion of each and the depth of the osteotomy they will create. (B.Y.1, B.Y.2, B.Y.3 and B.Y.4) The two osteotomes in the kit have a diameter of 3.7 mm, and a dynamic stopper that can be adjusted to the desired depth of the osteotomy planned from 1-4 mm according to the protocol instructions.

Baranes technique surgical protocol

The procedure is started by evaluating the CBCT of the posterior maxilla and the height of the crest inferior to the maxillary sinus and the desired location of the placement of the implants. (Figure 2)

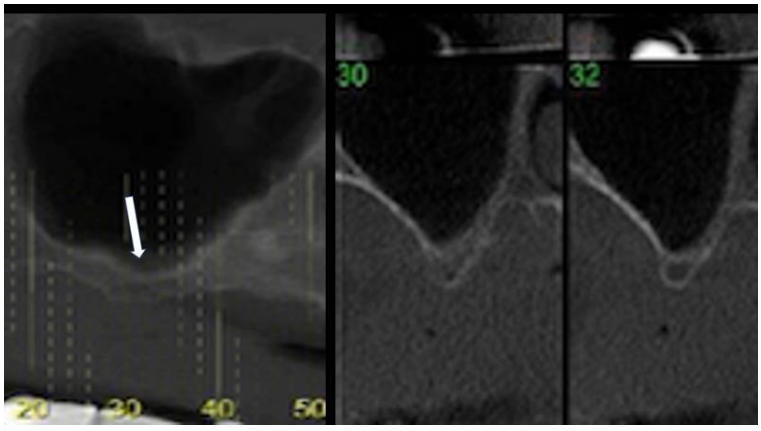

Figure 2: CBCT views showing minimal crestal bone height insufficient for placement of implants without sinus augmentation.

The procedure is initiated under local anesthesia with infiltration of 2% Lidocaine with1:100,000 adrenaline (epinephrine) concentration. A crestal incision located slightly palatal to the ridges midline is made with two short vertical releasing incisions mesial and distally, and minimal full thickness flap is reflected to expose the crestal bone. Once the crestal bone is exposed the osteotomy is done at 600-800 RPM with maximal torque utilizing the B.Y. diamond burs in a sequence of lengths starting with the B.Y.1 until the crestal bone is completely penetrated. The RPM is raised if needed from 600 to 800 RPM in correlation with the bone density and its resistance to the drilling and the milling process.

The B.Y.1 diamond bur is mounted on a contra angel surgical handpiece and utilized with sterile saline irrigation. Once the B.Y.1 during drilling/milling reach to its stopper, the second B.Y.2 is used then B.Y.3 and B.Y.4 as needed until the crestal bone is completely perforated and the sinus membrane is visualized. When the bone has been perforated, the clinician can feel immediately that the B.Y. bur milling friction does not have the same resistance as when it was within the bone, the osteotomy should be stopped to avoid tearing the membrane with further advancement of the bur. During the milling process a residue of bone in a mushy creamy consistency is formed in between the bur and the sinus membrane. In addition, due to the concave design of the bur a thin bony plate remains adhered to the sinus membrane. (Figure 3) Therefore the design of the B.Y. burs and the existing limiting stoppers prevents tearing of the sinus membrane by over drilling and guaranteeing an outstanding predictable safe approach.

Following the osteotomy, the lifting of the sinus membrane is done gradually with the osteotomes. (Figure 4) The length of the osteotome that is introduced can be limited by its stopper from 1-7 mm according to the protocol. At this stage we don't want to lift the sinus membrane more than 6-7 mm, as our goal is to increase the crestal height to 4-5 mm which will be sufficient for placement of the implant and gain primary stability after bone consolidation at the second stage. Lifting more than 6-7 mm at this stage does not have any additional benefit, however it increases the risk of tearing the sinus membrane.

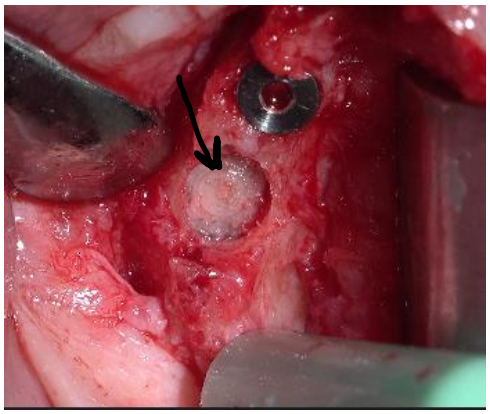

Figure 3: Initial preparation of the crestal bone where the implant is to be placed using the B.Y. burs consecutively until the bone is perforated, as it can be seen the membrane is detached and a bone plate always remains in the middle of the osteotomy due to the design of the B.Y burs.

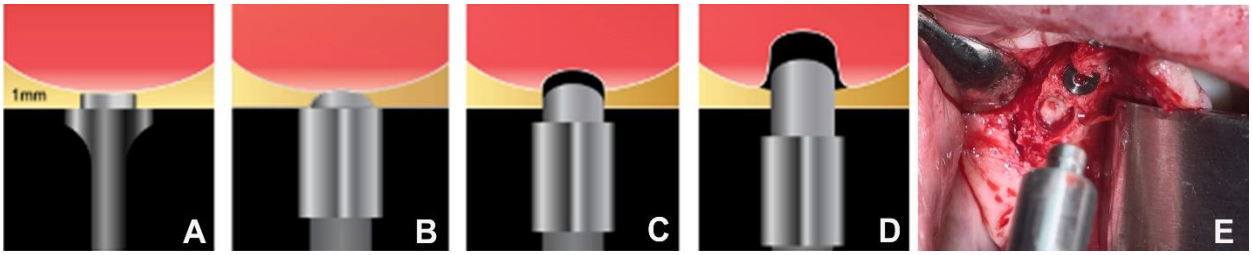

Figure 4: The Baranes Technique sequence with initiation of the osteotomy (A), sequential use of osteotomes lifting the sinus membrane (B-D) and result after elevation (E).

Lifting of the sinus membrane is initiated by restricting the osteotomes length to one millimeter more from the final B.Y. bur length that was used at the time of creation of the osteotomy when the bone was perforated, For example if the last B.Y. length was 3 mm, the osteotome length in its first introduction should be 4 mm, and gradually adding one millimeter each time the osteotome is re-introduced to lift the sinus membrane to 6 or 7 mm, but no higher. As mentioned earlier, lifting more than 7 mm is not necessary and can jeopardize the procedure by tearing the membrane.

After lifting the membrane with the osteotomes, the augmentation of the sinus cavity is accomplished with "Bond Apatite® bone cement. A bone graft cement like Bond Apatite® is the material of choice due to its viscosity and cementing abilities as well its true regeneration properties. The material is activated within its syringe and ejected into a sterile dish, immediately after a piece of dry gauze is placed above the material and with finger pressure over the gauze for 1-2 seconds the material is pressed to remove residual moisture. The gauze is removed, and the material is ready to be reloaded into the bone carrier syringe. (Figure 5)

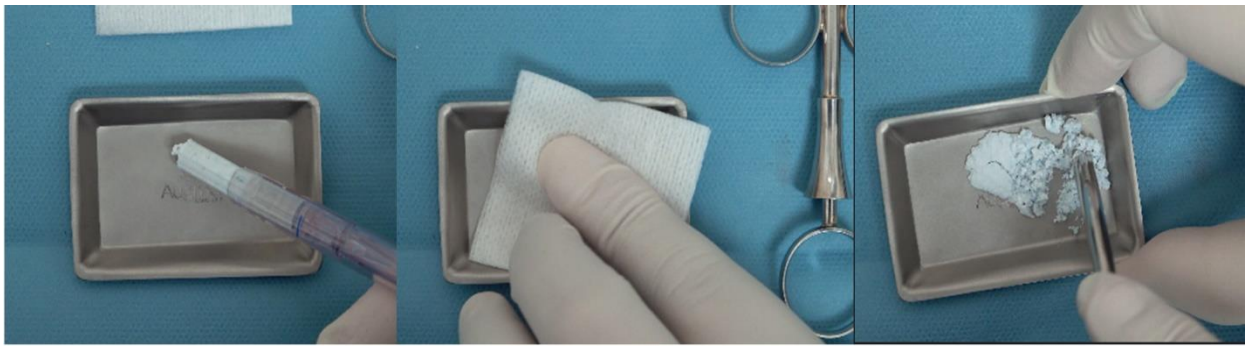

Figure 5: Following mixing the Bond Apatite in the syringe, it is expressed into a sterile dish (left), excess moisture is removed with sterile gauze pressed over the material (middle) and material is broken up ready to be loaded into the sinus graft syringe (right).

Following loading into the bone carrier, the syringe is introduced into the osteotomy and extruded into the elevated sinus area. An osteotome with the same final length of the osteotome that was used during the lifting of the membrane is then utilized to push the graft material into the elevated sinus area. (Figures 6 and 7) The bone carrier is loaded again, and the graft is introduced into the osteotomy now the length of the osteotome is reduced by one millimeter from its last introduction. then another layer of Bond Apatite® is injected into the osteotomy and the length of the osteotome is reduced again by 1 mm and so on, each time filling the osteotomy with the graft another millimeter is reduced until the osteotome length has reached 1 mm and the osteotomy is almost filled completely with the graft material. At this stage a final amount of graft is placed to cover the osteotomy and is compacted with dry sterile gauze and finger pressure for 3 seconds. The flap is then closed with PGA 4.0 resorbable sutures or a non-resorbable suture depending on the practitioners preference. However, chromic gut or gut sutures are not recommended as they might resorb too fast. Soft tissue closure is done without a membrane due to the barrier effect of this type of graft material, After suturing an intraoral wound dressing "Augmashield" (Augma Biomaterials) was placed on top of the sutured area to enhance initial soft tissue healing. A post-op radiograph is taken (Figure 8) and post operative instructions are given to the patient with analgesics prescription.

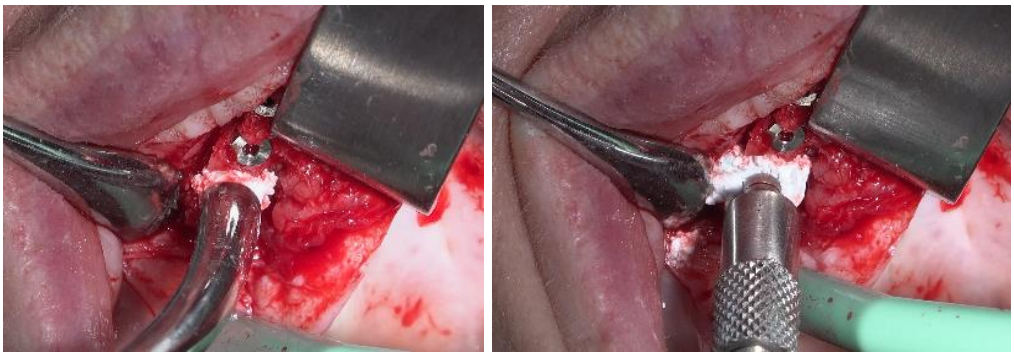

Figure 6: Bond Apatite injected it the osteotomy with the sinus graft syringe (left) and compacted vertically with the osteotome (right).

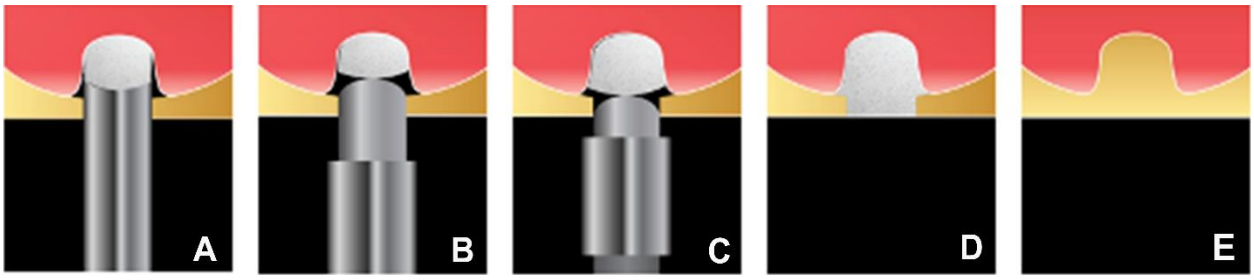

Figure 7: Illustrations showing placement of the graft material with the sinus graft syringe (A), compaction with the osteotomes with depth gauge set (B and C), membrane elevated and graft placed (D) and height following graft healing (E).

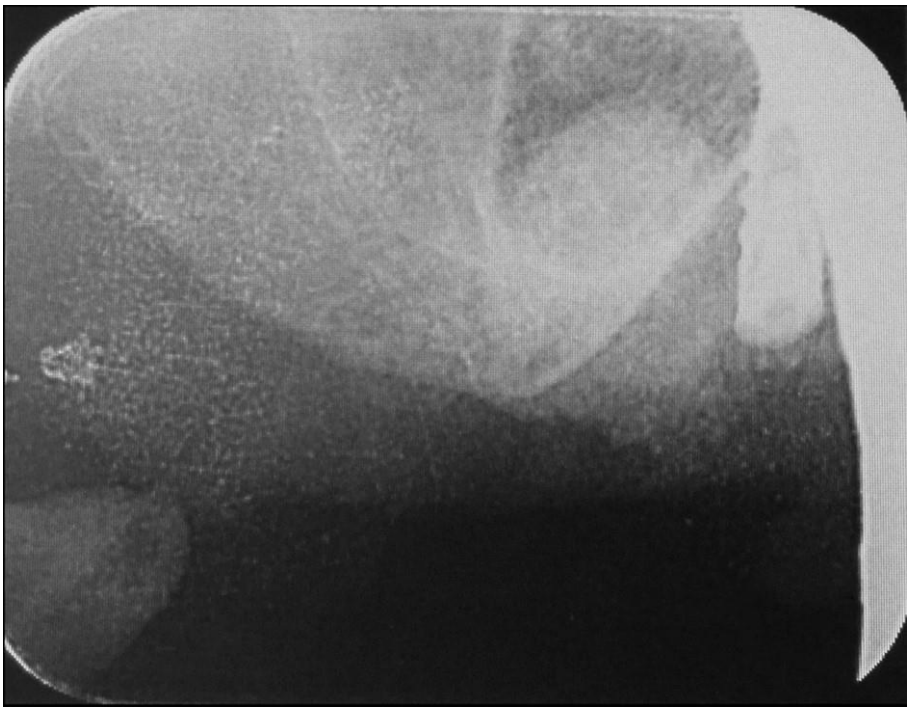

Figure 8: Post-op radiograph to document crestal sinus augmentation.

While pushing the material into the sinus due to its viscosity and cementing properties the material is dispersed uniformly within the sinus cavity and in this way the sinus can be augmented safely without disbursement through the sinus as may happen with particulate type graft materials. The site is left to heal and allow bone consolidation for 4-5 months. During that time period we expect a vertical resorption of about 2 mm from the height that we lifted at the first procedure. Following that healing period re-evaluation is performed using a CBCT to determine that sufficient bone height at the crestal level has been achieved. When this is confirmed the second phase of the "Summers technique" can be performed for further augmentation of the sinus and simultaneous implant placement.

Review of the study cases:

The complications inherent with the lateral sinus augmentation approach include potential for tearing of the sinus membrane and postoperative issues related to the more extensive flap that is required to complete the procedure. This led to development of a crestal approach with a staged technique when minimal crestal height is present that will not allow simultaneous implant placement. The approach described reduces the potential for sinus membrane tearing and with a less extensive flap required post-operative issues such as discomfort during healing are greatly minimized. Additionally, the bi-phasic calcium sulphate's ability to set solid it situ and by its complete replacement to regenerate the patient's own bone in the elevated sinus area aids in tenting the sinus membrane. This eliminates the potential for lateral spread of the graft material and loss of height during graft healing and during the second stage of implant placement during the "Summers technique" procedure.

The Baranes technique, utilizing the properties of bi-phasic calcium sulphate with its hydroxyapatite component, allows obtaining an osseous vertical height gain of 4 to 5 mm to permit sufficient bone to stabilize the implant at later placement following graft healing. The materials properties also allow elimination of a membrane reducing the cost of treatment materials traditionally utilized without affecting healing of the grafted site by either loss of graft material during initial site healing due to potential oral exposure or soft tissue invagination into the graft material before it can organize. The radiographic appearance following 4-months of graft healing does not reflect the clinical reality, as the immature (young) bone is still undergoing calcification as it matures and is replaced by host bone. Following the 4-month healing phase of the initial graft material, sufficient crestal height presents to allow initial stability of the implant and further crestal elevation can be accomplished at that surgical appointment. This allows placement of an implant of sufficient length that is suited for that clinical position in the posterior maxilla with integration of the implant at the osteotomy as the secondary crestal elevation is healing.

Fifty-one (51) patients were treated in the study that presented with a posterior edentulous space that was treatment planned

for implant placement. (Table 1) Each of the sites presented with an initial crestal height of 1 to 2.5mm. The Baranes technique was utilized achieving an initial crestal height of 4 to 5.2mm, with one case achieving 7mm following healing of the 1st stage crestal graft with Bond Apatite. Implants were placed at 2nd stage surgery with additional crestal lift allowing placement of a 10mm long implant, with one case having an 8 mm length implant was utilized.

Table 1:

	Gender	Age	Height of sub sinus residual bone.	Height of sub sinus bone 4 months post op.	Implant Size	Membrane Perforation
Cas 1	M	76	1	5	4.2X10	-
Cas 2	F	72	1	4	3.75X10	-
Cas 3	F	64	2	5	3.75X10	-
Cas 4	F	59	1.5	4.5	4.2X8	-
Cas 5	M	57	2	5	4.2X10	-
Cas 6	F	62	1	4.5	4.2X10	-
Cas 7	F	76	2.5	5	3.75X10	-
Cas 8	F	58	1	5	4.2X10	-
Cas 9	M	73	1	5	3.75X10	-
Cas 10	M	74	2	5.1	4.2X10	-
Cas 11	F	63	2	5	3.75X10	-
Cas 12	F	55	1	4.5	4.2X10	-
Cas 13	M	59	1.5	4.8	3.75X10	-
Cas 14	M	80	2	5.2	3.75X10	-
Cas 15	M	68	1	4.5	4.2X10	-
Cas 16	M	68	1.5	4	3.75X10	-
Cas 17	F	63	2.5	7	3.75X10	-
Cas 18	M	59	1.5	5.2	3.75X10	-
Cas 19	F	58	1.5	5	4.2X10	-
Cas 20	F	48	1.5	5	4.2X10	-
Cas 21	M	62	2	4	4.2X8	-
Cas 22	F	68	1.5	5	4.2X10	-
Cas 23	M	58	2	5	4.2X8	-
Cas 24	M	62	1	4.2	4.2X10	-
Cas 25	F	82	1	5	3.75X10	-

	Gender	Age	Height of sub sinus residual bone.	Height of sub sinus bone 4 months post op.	Implant Size	Membrane Perforation
Cas 26	F	82	1	4	3.75X10	-
Cas 27	M	74	1	5	4.2X10	-
Cas 28	M	74	1	5	3.75X10	-
Cas 29	F	56	1	4.5	3.75X10	-
Cas 30	M	56	1	4	3.75X10	-
Cas 31	M	56	1.5	5	3.75X10	-
Cas 32	F	62	1	5	3.75X10	-
Cas 33	F	64	1	5.5	4.2X8	-
Cas 34	M	62	1	5	3.75X10	-
Cas 35	M	67	1	5	4.2X10	-
Cas 36	M	67	2	6	3.75X10	-
Cas 37	F	55	3	7	4.2X10	-
Cas 38	F	55	1	5	/	-
Cas 39	F	57	1.5	4	4.2X8	-
Cas 40	M	72	1	5	3.75X10	-
Cas 41	M	72	2	5	3.75X10	-
Cas 42	M	76	1	6	3.75X10	-
Cas 43	M	67	1.5	5	3.75X10	-
Cas 44	M	67	1.5	5	4.2X10	-
Cas 45	M	38	1	5	4.2X10	-
Cas 46	M	38	1	7	4.2X10	-
Cas 47	M	68	3	6	4.2X10	-
Cas 48	M	68	4	7	4.2X10	-
Cas 49	F	70	1	5	3.75X10	-
Cas 50	F	72	1.5	5	4.2X10	-
Cas 51	F	72	2	6	4.2X10	

Conclusion:

By respecting the protocol, the Baranes technique allows a minimal technique sensitive approach for bone regeneration and vertical sub-sinus bone augmentation so it can be done safely and predictably for most of the clinicians less dependent of their experience and surgical skill without suffering the complications inherent in a lateral sinus approach. Thus, allowing creation of a stable

base to permit subsequent implant initial stability at placement after the initial augmentation has healed and immature bone is present at the 2nd surgery when the implant will be placed. Bond Apatite has been documented to convert to host bone over a 4–6-month period dependent on the volume of graft that had been placed and is well tolerated by host tissues, making it an ideal material for sinus augmentation. The materials hard setting prevents disbursement in the sinus during initial healing and eliminates loss of height during the healing that occurs with particulate graft materials when an implant is not present to tent the sinus membrane. Additionally the elimination of the need for a membrane reduces treatment costs for the patient as well as simplifies the surgical procedure for the practitioner.

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