ISSN 0973-2063 (online) 0973-8894 (print)

Bioinformation 22(8): 4640-4644 (2026)

BIOINFORMATION
Discovery at the interface of physical and biological sciences

BIOMEDICAL INFORMATICS

www.bioinformation.net
Volume 22(8)

Research Article

Received August 1, 2026; Revised August 31, 2026; Accepted August 31, 2026, Published August 31, 2026

DOI: 10.6026/973206300224640

SJIF 2026 (Scientific Journal Impact Factor for 2026) = 8.478
2022 Impact Factor (2023 Clarivate Inc. release) is 1.9

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Citation: Keerthivasan *et al.* Bioinformation 22(8): 4640-4644 (2026)

Evaluating the Khoury bone shell technique and indirect emergence profile transfer for maxillary esthetic zone reconstruction: A randomized controlled trial

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Abstract:
Rehabilitation of the maxillary esthetic zone requires predictable hard and soft tissue reconstruction. Therefore, it is of interest to compare the combined Khoury Bone Shell Technique protocol with a conventional protocol in 76 patients. Clinical, radiographic, esthetic and prosthetic outcomes were assessed after 12 months. The combined protocol significantly improved implant stability, esthetics, bone preservation and reduced surgical time. Thus, data shows the combined approach offers a predictable strategy for successful esthetic zone implant rehabilitation.

Keywords: Khoury bone shell technique (BST), emergence profile transfer, maxillary esthetic zone, implant prosthodontics, ridge augmentation

Background:
The maxillary esthetic zone, encompassing the anterior teeth from the first premolar to the contralateral first premolar, presents uniquely demanding requirements for implant-supported restorations **[1]**. Following tooth extraction, trauma, or pathology, bone and soft tissue loss in this region produces deficiencies that compromise both function and esthetics. Three-dimensional reconstruction of the alveolar ridge to support a naturally emerging implant crown requires meticulous surgical planning and technically exacting prosthetic protocols **[2].** Despite advances in guided bone regeneration (GBR) and implant design, achieving predictable volumetric gain in the anterior maxilla remains one of the foremost challenges in implant dentistry **[3].** The Khoury Bone Shell Technique (BST) was introduced as a refined method for horizontal and vertical ridge reconstruction using thin cortical bone shells harvested from the retromolar or symphyseal region. Unlike particulate graft techniques, the shell approach creates a rigid, well-vascularized compartment that stabilizes graft volume, resists resorption and allows predictable bone maturation **[4]**. The cortical shells function as both biological barrier and structural scaffold, reducing reliance on synthetic membranes and improving biocompatibility. Clinical case series have consistently showed favorable volumetric outcomes, particularly in severely resorbed ridges where conventional GBR may be insufficient **[5]**. Achieving an esthetically pleasing implant crown depends not only on adequate bone volume but also on faithful reproduction of the peri-implant emergence profile the three-dimensional contour transitioning from the implant platform through the soft tissue to the visible crown margin **[6]**. An improperly reproduced profile results in unnatural gingival contours, papilla collapse and peri-implant inflammation. The indirect emergence profile transfer technique utilizes the provisional restoration as a biologically active tool to sculpt and mature the peri-implant mucosa before encoding this architecture into a customized impression coping or digital scan **[7]**. Conventional impression protocols commonly employ stock copings that do not replicate the subgingival profile created by the provisional crown. This mismatch is a recognized cause of soft tissue collapse during transition to the final crown. Indirect emergence profile transfer ensures that the definitive prosthesis replicates the mature tissue profile with high fidelity **[8]**. The Pink Esthetic Score (PES) has become the standard tool for evaluating peri-implant soft tissue outcomes, with studies showing customized emergence profile protocols achieve superior scores over conventional techniques **[9]**. Despite recognition of the Khoury BST and indirect emergence profile transfer as individually effective, no randomized controlled trial has evaluated their combined application as an integrated surgical-prosthetic workflow. The synergy is theoretically compelling, as volumetric bone gain without prosthetic precision may yield suboptimal esthetics and vice versa. Furthermore, intraoperative parameters, crestal bone stability and patient-reported outcome measures (PROMs) collectively define holistic treatment success but remain inadequately compared between protocols **[10, 11]**. Therefore, it is of interest to evaluate and

compare intraoperative parameters and prosthetic outcomes of the Khoury BST combined with indirect emergence profile transfer against a conventional ridge augmentation and impression protocol in patients requiring implant rehabilitation of the maxillary esthetic zone.

Methodology:

Seventy-six adult patients requiring single-tooth implant rehabilitation in the maxillary esthetic zone (central incisor, lateral incisor, canine, or first premolar) were enrolled. Inclusion criteria required patients to be between 21 and 60 years of age with a healed extraction site exhibiting at least 3 mm of horizontal bone deficiency and/or 2 mm of vertical deficiency relative to the adjacent teeth, as measured on cone-beam computed tomography (CBCT). Patients were required to have adequate general health with no contraindications for elective oral surgery, a minimum of 3 mm of keratinized tissue at the adjacent teeth and good oral hygiene with a full-mouth plaque score below 20%. Exclusion criteria included uncontrolled systemic disease (*e.g.,* uncontrolled diabetes with HbA1c > 8%), heavy smoking (> 20 cigarettes/day), active periodontal disease, previous failed implants in the region and unwillingness to comply with the follow-up schedule. Informed written consent was obtained from all participants prior to enrollment. Computer-generated block randomization (block size 4) was performed using an online tool (www.sealedenvelope.com) and allocation was concealed in sequentially numbered, sealed envelopes opened at the time of surgery. Patients were allocated equally to either the experimental group (Khoury BST + indirect emergence profile transfer, n = 38) or the control group (conventional GBR with resorbable membrane + stock impression coping transfer, n = 38). The treating surgeon could not be blinded to group allocation; however, outcome assessors for PES, bone measurements and patient-reported outcomes were blinded throughout the study. In the experimental group, the Khoury BST was performed according to the original technique described by Khoury and Hanser. Cortical bone shells of 1.0–1.5 mm thickness were harvested from the retromolar region of the ipsilateral mandible using a piezoelectric device. The shells were fixed to the recipient site using titanium micro-screws (Stryker CMF, USA) to create a rigid compartment, which was subsequently filled with a mixture of autogenous bone chips and a xenograft (Bio-Oss, Geistlich, Switzerland) in a 1:1 ratio. A collagen membrane (Bio-Gide, Geistlich) was placed over the assembly before primary flap closure. After a healing period of 6 months, CBCT was repeated to verify bone volume and implants (Straumann BLT, SLA, Switzerland) were placed in the regenerated ridge. Implant stability quotient (ISQ) was recorded using resonance frequency analysis (Osstell, Sweden) at placement and at 8 weeks. Following implant placement, provisional crowns fabricated on titanium temporary abutments were delivered and conditioned the peri-implant mucosa for 8–12 weeks. Indirect emergence profile transfer was then performed by modifying a stock open-tray impression coping with addition silicone (Panasil, Kettenbach, Germany) injected incrementally around the provisional crown *in situ*, creating a customized coping that replicated the subgingival tissue architecture. Final impressions were made using a polyether material (Impregum, 3M ESPE) in a closed tray and all-ceramic zirconia crowns (Prettau 2 Dispersive, Zirkonzahn) were fabricated by a calibrated dental technician blinded to group allocation. In the control group, guided bone regeneration was performed using a resorbable collagen membrane (Bio-Gide) over a mixed graft (autogenous bone chips + Bio-Oss 1:1). Implants of the same system were placed after 6 months of healing at similar positions and axes. Provisional crowns were delivered but without a formal emergence profile conditioning protocol. Final impressions were made using a standard stock open-tray impression coping without subgingival modification. Identical crown materials and fabrication protocols were used in both groups. Primary outcome measures included: (1) intraoperative parameters (surgical time, intraoperative blood loss, incidence of membrane perforation, flap dehiscence and initial implant stability); (2) Pink Esthetic Score (PES) at crown delivery and at 12 months post-loading; (3) emergence profile transfer accuracy, quantified by superimposing digital scans of the provisional crown and the definitive crown using 3Shape Trios 4 intraoral scanner data and dedicated analysis software (GeoMagic, 3D Systems, USA); and (4) crestal bone levels on standardized periapical radiographs at implant placement, 6 months and 12 months post-loading. Secondary outcomes included keratinized tissue width, buccal mucosa thickness by ultrasound, modified Plaque Index, probing depth at implant sites, implant survival and patient satisfaction assessed by a validated visual analog scale questionnaire at 12 months. Statistical analyses were performed using IBM SPSS statistics version 28. Continuous variables with normal distribution were compared using independent samples t-tests, while non-normally distributed data were analyzed with the Mann-Whitney U test. Categorical variables were analyzed using chi-square or Fisher's exact test as appropriate. Longitudinal bone level data were analyzed with repeated-measures ANOVA. A significance level of $p < 0.05$ was applied throughout. Sample size was calculated to detect a 1.5-point difference in PES (SD = 2.0) with 80% power and $\alpha = 0.05$, yielding 34 patients per group; 38 per group were enrolled to account for 10% attrition.

Results:

Seventy-six patients completed the study to 12-month follow-up (38 per group). Mean age was 36.2 ± 9.4 years in the experimental group and 37.8 ± 8.7 years in the control group ($p = 0.42$). The male-to-female ratio and distribution of implant sites were comparable between groups. All implants achieved osseointegration (confirmed ISQ > 65 at 8 weeks) and no patient developed donor site morbidity requiring intervention. The Khoury BST group demonstrated statistically significant advantages across all intraoperative parameters. Mean surgical time was reduced by approximately 12 minutes compared to the control group and intraoperative bleeding was significantly lower. Membrane perforation, which directly compromises the graft compartment, occurred in only 3 patients (7.9%) in the experimental group versus 9 patients (23.7%) in the control group. Initial implant stability, as measured by ISQ at placement, was significantly higher in the experimental group, reflecting the superior bone density of the regenerated ridge. Flap dehiscence within the first 2 weeks was less frequent in the Khoury BST group (**Table 1**). The experimental group showed markedly superior prosthetic outcomes. Mean Pink Esthetic Score at crown delivery was 12.8 ± 1.4 in the Khoury BST group compared to 9.6 ± 1.9 in the control group ($p < 0.001$); with a clinically meaningful difference exceeding three points. Papilla Index scores were also significantly higher, indicating better papilla fill in the experimental group. Emergence profile transfer accuracy, as determined by digital superimposition, exceeded 91% in the experimental group versus 74.5% in the control group ($p < 0.001$). Provisional-to-final crown transfer fidelity demonstrated a similar trend. Crestal bone loss at 12 months was significantly lower in the Khoury BST group (0.41 ± 0.18 mm) compared to the control (0.79 ± 0.27 mm) (**Table 2**). Implant survival at 12 months was 97.4% in the experimental group (one implant removed due to peri-implantitis at 9 months) versus 86.8% in the control group (five implants failed; three due to insufficient osseointegration, two due to peri-implantitis). Buccal mucosa thickness and keratinized tissue width were significantly greater in the Khoury BST group, reflecting the superior tissue support provided by the augmented ridge. Peri-implant hygiene parameters and probing depths were also significantly better in the experimental group at 12 months (**Table 3**). Patient-reported satisfaction scores were significantly higher in the Khoury BST group across all evaluated domains. Overall esthetic satisfaction was reported as high by 94.7% of experimental group patients versus 76.3% of controls. Naturalness of gingival contour, post-operative discomfort levels and willingness to recommend the procedure all favored the experimental group. The greatest absolute difference was observed in gingival contour naturalness, where a 21-percentage-point gap separated the two groups (**Table 4**).

Table 1: Comparison of intraoperative and early outcomes between khoury BST and conventional groups

Parameter	Khoury BST Group (n=38)	Conventional Group (n=38)	p-value
Mean surgical time (min)	82.4 ± 11.3	94.7 ± 13.1	0.004
Intraoperative bleeding (mL)	18.2 ± 4.6	27.8 ± 6.3	0.002
Membrane perforation (n, %)	3 (7.9%)	9 (23.7%)	0.041
Shell stability (ISQ at placement)	72.6 ± 5.1	64.3 ± 6.8	<0.001
Flap dehiscence	2 (5.3%)	7 (18.4%)	0.043

Table 2: Prosthetic outcomes and emergence profile transfer accuracy at 12 months

Outcome Measure	Khoury BST Group	Conventional Group	p-value
Pink Esthetic Score (PES)	12.8 ± 1.4	9.6 ± 1.9	<0.001
Papilla Index Score (Jemt)	2.7 ± 0.5	2.0 ± 0.7	0.003
Emergence profile accuracy (%)	91.2 ± 3.8	74.5 ± 6.2	<0.001
Provisional-to-final transfer fidelity (%)	93.4 ± 4.1	76.8 ± 5.9	<0.001
Crestal bone loss at 12 months (mm)	0.41 ± 0.18	0.79 ± 0.27	0.001

Table 3: Implant survival rate and peri-implant soft tissue parameters at 12 months

Parameter	Khoury BST Group	Conventional Group	p-value
Implant survival rate (12 months)	97.40%	86.80%	0.019
Buccal mucosa thickness (mm)	2.91 ± 0.42	1.83 ± 0.51	<0.001
Keratinized tissue width (mm)	4.3 ± 0.8	3.1 ± 1.0	0.007
Modified Plaque Index (mPI)	0.48 ± 0.22	0.71 ± 0.31	0.012
Probing depth at 12 months (mm)	2.4 ± 0.6	3.2 ± 0.9	0.009

Table 4: Patient satisfaction outcomes at 12 months

Satisfaction Domain	Khoury BST Group (%)	Conventional Group (%)	p-value
Overall esthetic satisfaction	94.7	76.3	0.008
Gingival contour naturalness	92.1	71.1	0.006
Postoperative discomfort (low/none)	89.5	68.4	0.011
Crown shade and shape satisfaction	97.4	81.6	0.013
Willingness to recommend procedure	94.7	73.7	0.009

Discussion:

The results of this randomized controlled trial show that the combined application of the Khoury BST and indirect emergence profile transfer produces clinically and statistically significant improvements in intraoperative, prosthetic and patient-reported outcomes compared to a conventional augmentation and impression protocol in the maxillary esthetic zone. These findings are consistent with and extend the existing body of evidence for each component technique individually. The superiority of the Khoury BST in creating a stable regenerative compartment aligns with reports by Ayman *et al.* (2025) **[12]**, who showed in a prospective cohort that cortical shell techniques achieved a mean horizontal bone gain of 5.3 mm with a 94% complication-free rate in the anterior maxilla, significantly outperforming conventional particulate GBR in sites with critical bone deficiencies. The reduced membrane perforation rate observed in our experimental group (7.9% vs 23.7%) supports the mechanical advantage of rigid cortical shells over soft resorbable membranes in maintaining the regenerative space, particularly in the esthetic zone where thin buccal plates are prone to collapse under membrane tension. The improved initial ISQ values in the Khoury BST group at implant placement reflect the known advantage of cortical bone regenerated via shell technique, which matures into denser, more mechanically competent tissue compared to graft material confined only by a resorbable membrane. A multicenter study by Izzetti *et al.* (2025) **[13]**, similarly reported that implants placed in shell-regenerated ridges achieved higher ISQ values at placement and showed faster secondary stability gain compared to those placed in conventionally grafted sites, reducing the risk of early implant failure. The highly significant difference in emergence profile transfer accuracy (91.2% vs 74.5%) underscores the clinical importance of the indirect transfer technique. The PES differential of 3.2 points between groups at 12 months in our study exceeds the minimal clinically important difference of 1.5 points established by Vallecillo-Rivas *et al.* (2021) **[14]**. The experimental group's mean PES of 12.8 approached the threshold for excellent esthetic outcomes (PES ≥ 13), while the control group's mean of 9.6 indicated only acceptable results according to the classification by them. This difference was driven primarily by papilla fill scores, buccal mucosa level and soft tissue curvature all parameters directly influenced by the emergence profile architecture reproduced at the prosthetic stage. The significantly lower crestal bone loss in the Khoury BST group (0.41 vs 0.79 mm at 12 months) may reflect both the superior bone quality of the regenerated substrate and the more biomechanically optimized stress distribution afforded by the precise emergence profile. A finite element analysis study by Ceddia *et al.* (2022) **[15]**, showed that convex emergence profiles mimicking natural tooth root anatomy reduced stress concentrations at the crestal bone-implant interface by up to 34%, partially explaining the protective effect of accurate emergence profile transfer on marginal bone levels observed in our clinical data. The patient satisfaction outcomes in our study, with 94.7% of the Khoury BST group reporting high overall esthetic satisfaction versus 76.3% in the control group, mirror findings by Frantzopoulos *et al.* (2025) **[16]**, who reported that patients receiving customized emergence profile protocols in the anterior maxilla scored significantly higher on the Oral Health Impact Profile-14 (OHIP-14) and Visual Analog Scale satisfaction measures, attributing the difference specifically to the naturalness of the gingival contour rather than crown shade or shape. The convergent evidence from PROMs and clinical assessments in our trial strengthens the case for integrating both the Khoury BST and indirect emergence profile transfer as standard of care in esthetic zone implant rehabilitation.

Conclusion:

We show that combining the Khoury Bone Shell Technique (BST) with indirect emergence profile transfer significantly outperforms conventional protocols across intraoperative, prosthetic, soft tissue and patient satisfaction outcomes in the maxillary esthetic zone. The integrated workflow highlights the complementary role of precise bone regeneration and faithful soft tissue transfer in achieving predictable anterior implant esthetics. Further multicenter trials with longer follow-up are warranted to confirm durability and cost-effectiveness for routine clinical use.

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