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Clinicians' Perspectives on Regenerative Implant Dentistry: A Cross-Sectional Survey

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ABSTRACT

Background and aim: Ridge preservation (RP) and guided bone regeneration (GBR) are widely used regenerative procedures for maintaining alveolar ridge dimensions and improving soft tissue management and augmentation outcomes following tooth extraction and implant therapy. The use of biologic materials has further enhanced regenerative outcomes and treatment predictability. This study aimed to evaluate clinicians' experiences and perceptions regarding RP, GBR, biologic materials, soft tissue augmentation, and factors influencing successful regenerative outcomes in dental practice.

Material and methods: A cross-sectional survey were conducted among 410 dental clinicians involved in implant dentistry and regenerative procedures. Data were collected using a structured questionnaire that addressed treatment planning, graft materials, biologics, soft-tissue management, complications, digital imaging, and clinical outcomes.

Results: Most clinicians reported favorable outcomes with RP and GBR procedures, particularly when biologics and proper soft tissue management were incorporated. Accurate defect assessment, appropriate material selection, and surgical precision were considered the main factors contributing to successful outcomes. Soft tissue management and procedural costs remained important clinical challenges.

Conclusions: The findings suggest that evidence-based RP and GBR protocols combined with biologic materials may improve treatment predictability and clinical outcomes. Continuous professional education and standardized clinical protocols are recommended to optimize regenerative dental care.

1. Introduction

Optimal bone and tissue support, appropriate biocompatibility, and a good design can substantially affect the success of dental implants.^[1] Nevertheless, the physiological reabsorption of the bone after extraction often results in a marked reduction of ridge thickness and height, preventing proper implant positioning and prognosis.^[2] To address these problems, ridge preservation and bone regeneration techniques have become essential treatment modalities in modern implant therapy.^[3] Over the last 10 years, improvements in graft material properties, advances in membrane technology, expanded flap design options, and the introduction of biological agents have substantially increased the predictability of regenerative procedures.^[4] Regeneration of hard and soft tissues has become an integral part of contemporary implant dentistry, largely due to the predictable resorption pattern of the alveolar ridge after tooth extraction.^[5] Several studies have shown that the alveolar process resorbs horizontally by 50% within 6 months following tooth extraction, and that the buccal plate is most susceptible to atrophy.^[6] This predictable change in dimension has led to the development of ridge-preservation approaches designed to retain ideal bone volume for future implant placement.^[7] The literature on spontaneous healing of

extraction sockets in the early days focused on the concept of spontaneous healing, but subsequent evidence showed that extraction alone frequently resulted in inadequate ridge dimensions, emphasizing the importance of using ridge preservation and guided bone regeneration (GBR) techniques.^[8] The choice of the grafting material is a fundamental factor in regenerative success. Until now, allogeneic and xenogeneic grafts have been the most widely investigated biomaterials due to their osteoconductive properties and high long-term volume stability.^[9] Comparative studies revealed that allografts differ from xenografts in terms of dimensional stability, as allografts remodel more rapidly and are therefore recommended in situations where rapid implantation is required.^[10] Although autogenous bone is regarded as the gold standard for its osteogenic capacity, its use is constrained by donor-site morbidity and unpredictable resorption.^[11] New alloplastic and composite graft materials have expanded available options, but their long-term efficacy is often cited as inferior to that of biologically based replacements.^[12] The defect morphology, the thickness of the buccal plate, and the presence of dehiscence defects are all determinants of successful grafting.^[13] The choice of membranes, resorbable and non-resorbable, has also been widely assessed in the regenerative literature. Non-resorbable membranes, particularly in-

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forced PTFE forms, are statistically superior at maintaining space and should be employed for large defects or vertical augmentation.^[14] However, their complication rates are high, with membrane exposure being the most common. Resorbable collagen membranes are more surgically manageable, have lower exposure rates, and thus remain the ideal material for ridge preservation in cases of small-to-moderate defects.^[15] Previous studies have underscored the importance of tension-free primary closure, as flap tension is a significant predictor of membrane exposure and regenerative failure. Procedures such as periosteal releasing incisions, flap advancement, and microsurgical suturing have been shown to enhance regenerative outcomes.^[16] significantly. The use of biologics is an exciting, up-and-coming field in regenerative dentistry. Platelet-rich fibrin (PRF) has been increasingly used because it is an autologous product that is easy to prepare and promotes angiogenesis and soft-tissue healing.^[17] The literature suggests that PRF enhances initial wound stability, minimizes post-operative pain, and hastens soft-tissue healing. Enamel matrix derivatives (EMD) have shown high potential for regeneration in periodontal intrabony defects and are also being investigated for ridge preservation in soft tissue integration.^[18] Growth factors, including PDGF and BMPs, have shown promise in inducing bone formation; however, cost and regulatory barriers, along with potential adverse effects, have limited their clinical adoption.^[19] The incorporation of biologics into regenerative protocols remains an area of continued investigation, however.^[20] Simultaneous soft tissue augmentation is also a key factor, as soft tissue thickness and keratinized mucosa, along with other factors, directly impact aesthetics and peri-implant health.^[21] Connective tissue grafts (CTG) are recognized as the gold standard for augmenting soft tissues, with multiple studies reporting better long-term stability than free gingival grafts (FGG) or allogenic matrices.^[22] However, high patient morbidity rates, coupled with a donor shortage, have sparked greater enthusiasm for ADM and collagen matrices. Collagen matrices have been reported to provide similar esthetic results with lower morbidity, but shrinkage remains an issue.^[23] It has been demonstrated that good soft-tissue sealing around the implant may reduce marginal bone loss and achieve better long-term results.^[24] During the last decade, digital dentistry and artificial intelligence (AI) technologies have been introduced into diagnosis, treatment planning, and cosmetic outcomes.^[25] AI-based radiographic evaluation enables early detection of bone defects, more precise classification of socket shape, and better planning of GBR responsibilities.^[26] The use of CBCT-based volumetric measurements enables clinicians to quantify bone changes with high precision, compared with conventional radiographs.^[27] Although AI developments in regenerative dentistry are still in early stages, the literature suggests promising outcomes for improving treatment reproducibility and compliance with diagnostic criteria, as well as supporting decision-making.^[28] Nevertheless, a few standard protocols and clinical studies comparing AI-guided with conventional planning remain. Biologic adjuncts, including platelet-rich fibrin (PRF), enamel matrix derivatives (EMD), platelet-derived growth factor (PDGF), and bone morphogenetic proteins (BMPs), have increasingly been incorporated into regenerative procedures because of their favorable effects on angiogenesis, bone formation, and soft tissue healing.^[29, 30] In addition, soft tissue augmentation techniques such as connective tissue grafts (CTG), free gingival grafts (FGG), acellular dermal matrix (ADM), and collagen matrices have been widely used to enhance peri-implant tissue stability and esthetic outcomes.^[31, 32] More recently, advances in digital dentistry and artificial intelligence (AI) have expanded the possibilities for diagnostic imaging, defect assessment, and treatment planning through CBCT-based analysis and AI-assisted clinical decision-making.^[25, 34] Despite these developments, variations persist in clinicians' preferences and in the

routine implementation of these approaches in daily practice. Against this background, there is an increasing need for quantitative clinical evidence assessing the additive benefits of GBR procedures and biologics, when combined with soft tissue augmentation, for improving RP outcomes. The purpose of this study was to evaluate the effect of differing regenerative tactics, factors associated with enhanced clinical predictability, and emerging uses for biologics and AI-informed diagnostics to enhance regenerative potential. The results are anticipated to lead to standardized, evidence-based protocols that facilitate more predictable and successful GBR and soft-tissue outcomes across any clinical setting.

2. Material and methods

Study design

This descriptive cross-sectional survey was conducted to investigate clinicians' perspectives and current practice patterns regarding ridge preservation (RP), guided bone regeneration (GBR), biologic adjuncts, soft tissue augmentation, and artificial intelligence (AI)-assisted diagnostics in regenerative implant dentistry.

Participants

A total of 172 dentists actively involved in implant and regenerative dental procedures participated in this study. Participants represented different levels of clinical experience and various dental specialties related to implant dentistry and oral rehabilitation. Participation was voluntary, and all respondents provided anonymous responses.

Questionnaire development and data collection

Data were collected using a structured questionnaire developed after reviewing the contemporary literature on ridge preservation, guided bone regeneration, biologic agents, soft tissue management, and digital dentistry. The questionnaire consisted of several thematic sections, including:

1. Demographic and professional characteristics.
2. Ridge preservation protocols;
3. Guided bone regeneration techniques;
4. Use of biologic materials;
5. Soft tissue augmentation procedures;
6. Digital workflow and artificial intelligence applications;
7. Perceived clinical outcomes and overall satisfaction.

The questionnaire was distributed electronically, and only fully completed questionnaires were included in the final analysis.

Statistical analysis

Data were analyzed using descriptive statistical methods. Categorical variables were summarized as frequencies and percentages. The findings are presented to describe clinicians' preferences, perceptions, and current trends in regenerative implant therapy.

Ethical considerations

Participation in the study was voluntary and anonymous. All information was treated confidentially, and the study was conducted in accordance with the ethical principles outlined in the Declaration of Helsinki.

3. Results

The survey findings demonstrated that most clinicians reported favorable experiences with ridge preservation and guided bone regeneration procedures. Successful outcomes were commonly associated with accurate defect assessment, appropriate graft and biologic selection, and careful soft tissue

management. Clinicians indicated that biologic materials improved treatment predictability and enhanced regenerative outcomes. However, challenges related to soft tissue management and procedural costs were still reported in daily clinical practice.

Participants clinical background

Knowledge of the clinical background of participating clinicians is important for interpreting the variability, and indeed, reliability, of regenerative outcomes. Experience, degree of specialization, procedure numbers, use of biologics, and digital technology influence decision-making and competency, which, in turn, affect clinical outcomes for ridge preservation and GBR. Hence, baseline descriptions of 410 study participants are also essential for assessing their reported behaviors and clinical outcomes. Table 1 shows that the study population consisted of clinicians with generally moderate to high levels of clinical experience, and the largest group had 5–10 years of practice (45.6%), followed by those with more than 10 years (30.2%). This indicates that the majority of respondents were not novices, which strengthens the reliability of their reported clinical practices. In terms

of specialty distribution, periodontists represented the largest proportion (50%), followed by implant-focused general dentists (35.1%) and oral surgeons (14.9%). This suggests that clinicians with periodontal and implant-related expertise primarily manage ridge preservation and GBR procedures.

Regarding clinical workload, most participants performed 10–20 GBR/ridge preservation cases per month (38%), indicating moderate procedural exposure, while a smaller proportion reported high-volume practice (>20 cases/month, 26.9%). This reflects a mixed, yet clinically active, sample. A notable finding is the widespread use of biologic materials, with 68% of clinicians reporting routine use in more than half of their cases. Similarly, 72% of participants used digital technologies such as CBCT and intraoral scanning. This demonstrates a strong trend toward biologically driven and digitally supported regenerative implant dentistry in contemporary clinical practice. Overall, Table 1 characterizes a well-experienced, implant-oriented cohort with high adoption of biologics and digital workflows, suggesting that modern regenerative dentistry is widely integrated into routine clinical practice among specialists. (Table 1)

Table 1. Participants' clinical background.

Characteristics	Frequency (n)	Percentage (%)
Years of Clinical Experience		
<5 years	99	24.2
5–10 years	187	45.6
>10 years	124	30.2
Professional Specialty		
Periodontist	205	50.0
General Dentist (Implant Practice)	144	35.1
Oral Surgeon	61	14.9
Monthly Ridge Preservation/GBR Cases		
<10 cases	144	35.1
10–20 cases	156	38.0
>20 cases	110	26.9
Routine Biologic Use (>50% of Cases)		
Yes	279	68.0
No	131	32.0
Use of Digital Tools (CBCT/Intraoral Scan)		
Yes	295	72.0
No	115	28.0

Ridge preservation protocols

Ridge preservation is an important aspect of contemporary implant dentistry, aiming to reduce post-extraction dimensional changes and enhance the quality of the future implant site.^[21] The survey investigated care providers' approaches to the management of post-extraction socket defects, the method of selecting grafts, decision-making criteria for ridge preservation, the timing algorithms of choice, and preoperative clinical examination. Recognizing patterns would help us understand real-world clinical evidence and current trends in evidence-based regenerative dentistry. Table 2 describes clinicians' decision-making patterns and clinical approaches in ridge preservation (RP). The most frequently treated socket types were Type I (45.4%) and Type II (36.3%), indicating that clinicians most commonly manage less severe to moderately compromised extraction sites. In terms of graft selection, allografts (39.8%) and xenografts (37.1%) were the most commonly used materials, while alloplasts (14.9%) and autografts (8.2%) were used less frequently. This suggests a clear preference for bone

substitutes with good osteoconductive and handling properties rather than autogenous bone, likely due to reduced morbidity and easier clinical application. The primary indications for performing ridge preservation were thin or absent buccal bone plate (59.5%), moderate to severe bone loss (49.5%), esthetic zone considerations (45.6%), and planned delayed implant placement (42.9%). These findings highlight that RP is mainly used in cases where preservation of hard and soft tissue architecture is critical for future implant success. Immediate ridge preservation was the most commonly selected timing protocol (55.6%), followed by early (28.5%) and delayed approaches (15.9%), indicating a clinical preference for early intervention to minimize post-extraction resorption. Finally, most clinicians routinely recorded key diagnostic parameters, including buccal bone thickness (72%), alveolar width (68%), and soft tissue biotype (64.4%). This demonstrates a structured, evidence-based approach to treatment planning, with anatomical assessment central to decision-making. (Table 2)

Table 2. Ridge preservation protocols followed by respondents.

Variable	Category	Frequency (n)	Percentage (%)
Commonly Treated Socket Defects	Type I	186	45.4
	Type II	149	36.3
	Type III	75	18.3
Graft Materials Used	Allograft	163	39.8
	Xenograft	152	37.1
	Alloplast	61	14.9
	Autograft	34	8.2
Criteria for Choosing Ridge Preservation	Thin/Absent Buccal Plate	244	59.5
	Planned Delayed Implant Placement	176	42.9
	Moderate–Severe Bone Loss	203	49.5
	Esthetic Zone Extraction	187	45.6
Preferred Timing of Ridge Preservation	Immediate	228	55.6
	Early (1–2 weeks)	117	28.5
	Delayed (>6 weeks)	65	15.9
Pre-extraction Clinical Parameters Recorded	Buccal Plate Thickness	295	72.0
	Alveolar Bone Width	279	68.0
	Soft Tissue Biotype	264	64.4
	Keratinized Tissue Width	156	38.0

Guided bone regeneration (GBR) procedure details

Guided Bone Regeneration (GBR) is central to the reconstruction of alveolar defects and the enhancement of implant site development.^[33] Insight into real-world surgical strategies and predictability can be gained by understanding clinicians' selection of membranes, flap design, suture patterns,

and management of complications. To identify standard practices and difficulties encountered, we administered a questionnaire regarding GBR procedural choices and complications. The resorbable membranes and full-thickness flaps were preferred over tent folds for GBR. In contrast, the periosteal releasing incision technique and interrupted suturing resulted in

tension-free closures, as shown in the table. Exposure of the membrane was the most common intraoperative complication, and swelling and wound dehiscence were common post-operative complications. The findings presented in Table 3 highlight current clinical preferences and procedural patterns in guided bone regeneration (GBR). The results demonstrate a predominant use of resorbable membranes (69.8%), indicating a clinical preference for materials that reduce the need for secondary surgical removal and improve post-operative manageability. In contrast, non-resorbable membranes remain less frequently used (30.2%), likely due to their higher complication risk and greater technical demands. Full-thickness flap designs were the most commonly employed approach (65.1%), suggesting that clinicians favor surgical techniques that provide adequate access and visibility

for defect management. Additionally, the frequent use of periosteal releasing incisions (75.1%) underscores the critical importance of achieving tension-free primary closure, widely recognized as a key determinant of GBR success. Interrupted suturing was the predominant closure technique (66.6%), underscoring reliance on conventional, controllable suturing methods to ensure wound stability. Regarding complications, membrane exposure (34.9%) was the most frequently reported intraoperative issue, while post-operative swelling (56.8%) was the most common post-operative complication. These findings indicate that, despite advancements in GBR materials and techniques, soft tissue management and wound stability remain major clinical challenges that influence treatment predictability. (Table 3)

Table 3. GBR Procedure details reported by respondents.

Variable	Category	Frequency (n)	Percentage (%)
Membrane Used in GBR	Resorbable	286	69.8
	Non-resorbable (e.g., Ti-reinforced)	124	30.2
Flap Design Used	Full-thickness flap	267	65.1
	Partial-thickness flap	59	14.4
	Envelope flap	54	13.2
	Tunneling technique	30	7.3
Techniques to Achieve Tension-free Closure	Periosteal releasing incisions	308	75.1
	Vertical releasing incisions	167	40.7
	Undermining of tissue	191	46.6
Suturing Techniques Used	Interrupted sutures	273	66.6
	Mattress sutures	196	47.8
	Cross-mattress sutures	104	25.4
	Membrane exposure	143	34.9
Most Common Intraoperative Complications	Graft washout	87	21.2
	Flap perforation	62	15.1
	Swelling	233	56.8
Most Common Postoperative Complications	Early wound dehiscence	121	29.5
	Infection	56	13.7

Biologics application

Biologics are becoming increasingly significant for improving bone quality and quantity in tooth extraction defects.^[24] Their application in ridge preservation and guided bone regeneration (GBR) has yielded improved angiogenesis, a shorter healing period, enhanced graft integration, and a lower incidence of post-operative complications. The survey elicited clinicians' preferences for biologics and the defect-specific factors that contribute to their choice of each biologic. Over time, indications for soft tissue substitutes in abdominoperineal resection, patient-related influences on selection, and

consent practices have been examined. Below, we take a closer look at the biologic agents respondents preferred. Table 4 illustrates clinicians' preferences regarding biologic agents and the clinical rationale underlying their use in regenerative procedures. The results show that PRF/PRP (65.4%) are the most commonly utilized biologics, reflecting their autologous origin, ease of preparation, cost-effectiveness, and favorable biological properties. Other biologics, such as EMD (27.3%), PDGF (17.3%), and rhBMP-2 (11.2%), were used less frequently, likely due to higher costs and limited

accessibility. The primary indications for biologic use were enhancement of soft tissue healing (56.8%) and improvement of bone regeneration (46.1%), suggesting that clinicians primarily employ these agents as biological enhancers rather than primary regenerative substitutes. The selection of collagen matrices and acellular dermal matrices (ADM) was mainly associated with thin gingival phenotype (48.3%), peri-implant soft tissue deficiency (33.9%), and situations where autogenous grafts were not feasible or declined by patients (40.7%). Systemic and behavioral factors, particularly smoking (52.2%) and diabetes (42.9%), significantly influenced biologic

selection, highlighting the importance of patient risk stratification in regenerative planning. Furthermore, consent-related data indicate that clinicians most frequently discuss expected benefits (74.4%) and treatment costs (70.0%), underscoring the importance of ethical transparency and financial considerations in biologic therapies. Overall, these findings suggest that biologics are widely integrated into clinical practice, with their use being strongly guided by wound-healing objectives, patient-specific risk factors, and economic considerations.

Table 4. Biologics use and clinical decision patterns among respondents.

Variable	Category	Frequency (n)	Percentage (%)
Biologics Most Commonly Used	PRF/PRP	268	65.4
	EMD	112	27.3
	PDGF	71	17.3
	rhBMP-2	46	11.2
Reasons for Selecting Specific Biologics	Enhancing Soft Tissue Healing	233	56.8
	Improving Bone Regeneration	189	46.1
	Managing Large/Complex Defects	121	29.5
	Reducing Risk of Infection	142	34.6
Indications for Collagen Matrix / ADM Use	Thin Tissue Biotype	198	48.3
	Patient Refusal of Autogenous Graft	167	40.7
	Multiple Adjacent Recession Sites	115	28.0
	Peri-implant Soft Tissue Deficiency	139	33.9
Patient Factors Influencing Biologic Selection	Smoking	214	52.2
	Diabetes	176	42.9
	Poor Oral Hygiene	163	39.8
	Immune-compromised Status	87	21.2
Consent Information Provided	Cost of Biologics	287	70.0
	Benefits & Expected Outcomes	305	74.4
	Risks/Limitations	223	54.4
	Off-label Use Disclosure	129	31.5

Soft tissue augmentation practices

Soft tissue grafting is a fundamental requirement in implant and periodontal regenerative therapy, which impacts esthetic results and peri-implant health (22). Different methods, such as connective tissue grafts (CTG), free gingival grafts (FGG), acellular dermal matrices (ADM), or collagen matrices, are selected based on defect characteristics, patient factors, and the clinician's preference. This article provides detailed counts of the techniques used, including their general principles (Table 5), reasons for

performing simultaneous augmentation, factors that determine the site from which bone should be harvested, and related complications, as well as what is performed and on what criteria by slightly over two-fifths of five clinicians. Table 5 presents the clinical trends in soft tissue augmentation techniques and decision-making criteria. The results show that connective tissue grafts (CTG) (52.4%) remain the most frequently used technique, reaffirming their status as the gold standard for peri-implant soft tissue augmentation due to their predictable outcomes and long-term stability. Free gingival grafts (FGG) were

less commonly used (20.7%), while acellular dermal matrices (ADM) (14.6%) and collagen matrices (12.2%) were selected in more limited clinical scenarios. Simultaneous soft tissue augmentation was most commonly indicated in cases with a thin gingival phenotype (58.5%), a lack of keratinized tissue (46.3%), and high esthetic demands (39.0%), demonstrating that both functional and esthetic parameters strongly influence clinical decision-making. Donor site selection was primarily determined by tissue thickness (63.4%) and proximity to the surgical site (34.1%), indicating a balance between biological suitability and reduced surgical morbidity. The most frequently reported complications included flap or graft dehiscence (37.8%) and graft shrinkage (26.8%), which remain significant limitations affecting the long-term stability of soft-tissue outcomes. Post-operative management was highly standardized, with widespread use of chlorhexidine

rinses (78.0%), antibiotics (65.9%), and strict avoidance of brushing at the surgical site (85.4%). This reflects a consistent effort to optimize healing conditions and minimize post-operative complications across clinical settings. Overall, the findings demonstrate that while CTG remains the dominant technique, there is a gradual integration of biomaterial-based alternatives, driven by considerations of patient morbidity, esthetic demands, and clinical feasibility. As illustrated in Table 5, connective tissue grafts were the most frequently used soft-tissue augmentation technique and were placed mainly in thin periodontal phenotypes lacking adequate keratinized tissue. The donor site was chosen primarily based on tissue thickness and esthetic concerns, with dehiscence and graft shrinkage as the most common complications; however, for most clinicians, post-operative care protocols were standardized.

Table 5. Soft tissue augmentation practices among respondents.

Variable	Response Categories	Frequency (n)	Percentage (%)
Most Used Soft Tissue Augmentation Technique	CTG	215	52.4
	FGG	85	20.7
	ADM	60	14.6
	Collagen Matrix	50	12.2
Criteria for Simultaneous Soft Tissue Augmentation with Implant Placement	Thin gingival phenotype	240	58.5
	Lack of keratinized tissue	190	46.3
	High esthetic demand	160	39.0
	Existing recession defect	120	29.3
Factors Influencing Donor Site Selection	Tissue thickness	260	63.4
	Proximity to the surgical site	140	34.1
	Minimizing patient morbidity	110	26.8
	Esthetic zone requirements	95	23.2
Most Common Soft Tissue Complications	Flap/graft dehiscence	155	37.8
	Graft shrinkage	110	26.8
	Partial tissue necrosis	65	15.9
Postoperative Care Protocols Followed	Donor-site pain/bleeding	80	19.5
	Chlorhexidine rinse	320	78.0
	Antibiotics	270	65.9
	Soft diet for 7–10 days	300	73.2
	Avoid brushing the surgical site	350	85.4

Outcome measurements and clinical results

The findings presented in Table 6 demonstrate the outcome assessment methods and clinical results reported by clinicians following regenerative

procedures. Cone-beam computed tomography (CBCT) was the most frequently used volumetric measurement method (50.0%), followed by

intraoral scanning (35.4%) and caliper measurements (14.6%), highlighting the increasing reliance on digital technologies for quantitative evaluation of regenerative outcomes. Among the clinical parameters recorded at baseline and follow-up, ridge width change was the most commonly assessed variable (85.4%), followed by ridge height change (70.7%), soft tissue thickness (64.6%), and gain in keratinized tissue width (56.1%). Regarding treatment effectiveness, 42.7% of respondents reported maintaining at least 80% of ridge width after ridge preservation procedures, while 40.2% reported maintaining between 60% and 79% of the original ridge dimensions. Furthermore, 50.0% of clinicians reported a gain of 1–2 mm in keratinized tissue width following soft tissue augmentation. These outcome measures are

consistent with current recommendations for evaluating regenerative success, which emphasize radiographic bone preservation, peri-implant soft tissue stability, and patient-centered outcomes (34-36). Membrane exposure (37.8%), graft shrinkage (30.5%), and soft-tissue dehiscence (26.8%) were the most common complications associated with compromised regenerative outcomes. Collectively, these findings suggest that clinicians primarily evaluate treatment success based on preservation of ridge dimensions, soft-tissue stability, and the absence of post-operative complications, in agreement with contemporary evidence-based assessment protocols (34,37,38). (Table 6)

Table 6. Clinicians' perceptions of regenerative treatment outcomes.

Variable	Response Categories	Frequency (n)	Percentage (%)
Volumetric Measurement Method Used	CBCT	205	50.0
	Intraoral Scan	145	35.4
	Caliper Measurement	60	14.6
Outcome Measures Recorded at Baseline & Follow-Up	Ridge width change	350	85.4
	Ridge height change	290	70.7
	Soft tissue thickness	265	64.6
	Keratinized tissue width gain	230	56.1
	≥80% maintenance	175	42.7
Average Ridge Width Maintained After Preservation	60–79% maintenance	165	40.2
	<60% maintenance	70	17.1
	≤1 mm	95	23.2
Average Keratinized Tissue Gain After Augmentation	1–2 mm	205	50.0
	>2 mm	110	26.8
	Membrane exposure	155	37.8
Complications Associated with Reduced Regenerative Outcomes	Graft shrinkage	125	30.5
	Soft tissue dehiscence	110	26.8
	Infection	65	15.9

Workflow, documentation, and billing

Table 7 summarizes clinicians' workflow patterns, documentation protocols, and billing-related challenges associated with regenerative procedures. Nearly half of the respondents (46.3%) reported using a comprehensive documentation protocol comprising clinical photographs, CBCT records, detailed clinical notes, and informed consent forms, underscoring the importance of thorough record-keeping in contemporary regenerative practice. Defect morphology and defect type were identified as the primary determinants influencing treatment planning (34.1%), followed by systemic health factors such as diabetes, smoking status, and medication use (23.2%). Financial considerations also played a significant role, with inadequate insurance coverage or reimbursement representing the most

frequently reported billing challenge (40.2%). Other notable barriers included the high cost of biologic materials (26.8%) and the lack of standardized billing codes (18.3%). In terms of compliance requirements, maintaining serial clinical photographs (30.5%) and obtaining pre- and post-operative CBCT documentation (25.6%) were perceived as the most difficult aspects of clinical documentation. Overall, the results indicate that although structured documentation protocols are widely adopted, administrative and financial challenges continue to influence the implementation and standardization of biologic-assisted regenerative therapies, which remain important considerations in contemporary implant practice.^[5, 6]

Table 7. Workflow, documentation, and billing practices.

Variable	Category	Frequency (n)	Percentage (%)
Documentation protocol (primary approach used)	Full documentation package (photos + CBCT + detailed notes + consent)	190	46.3
	Photos + detailed notes (no CBCT)	95	23.2
	Photos only	50	12.2
	Detailed notes only	40	9.8
	Consent only/other minimal documentation	35	8.5
Factors influencing treatment planning (primary factor)	Defect morphology/type	140	34.1
	Patient's systemic health (diabetes, smoking, meds)	95	23.2
	Esthetic zone requirements	80	19.5
	Cost & patient affordability	60	14.6
	Availability of biologics/membranes	35	8.5
Challenges in billing biologic-assisted procedures (primary challenge)	Inadequate insurance coverage/reimbursement	165	40.2
	High biologic material cost (patient charge issues)	110	26.8
	Lack of standardized billing codes (CDT/CPT ambiguity)	75	18.3
	Documentation rejection/insurer disputes	40	9.8
	Patient refusal/preference to pay out-of-pocket	20	4.9
Most difficult compliance requirement to maintain (primary)	Serial clinical photographs (consistency)	125	30.5
	CBCT documentation (pre/post imaging)	105	25.6
	Detailed procedural notes (granularity/timeliness)	90	22.0
	Biologic usage logs/batch tracking	60	14.6
	Insurance paperwork/prior-authorization forms	30	7.3

Integration of artificial intelligence in diagnostics and treatment planning

The survey evaluated clinicians' perceptions of integrating artificial intelligence (AI) into regenerative and implant dentistry. Participants were asked about their familiarity with AI-assisted technologies, their current use in clinical practice, and their opinions regarding the potential benefits of AI in diagnosis, treatment planning, and outcome assessment. Most respondents expressed a positive attitude toward incorporating AI into implant dentistry and regenerative procedures. Clinicians perceived that AI-based systems could assist in radiographic interpretation, identification of anatomical landmarks, assessment of bone quality, and optimization of treatment planning workflows. These findings are in accordance with recent literature suggesting that AI has considerable potential to support clinical decision-making and improve diagnostic efficiency in dentistry.^[28, 40]

Table 8 presents clinicians' experiences and perceptions regarding the integration of artificial intelligence (AI) into regenerative and implant dentistry. CBCT segmentation was the most commonly utilized AI application (40.2%), followed by caries and bone-loss detection (24.9%), while 20.0% of respondents reported using both technologies simultaneously.

The most valuable diagnostic information provided by AI systems was precise assessment of defect dimensions (34.9%) and estimation of buccal plate thickness (24.9%). Importantly, 40.0% of clinicians reported that AI significantly improved the accuracy of defect classification, while an additional 30.0% perceived a moderate improvement. These findings are consistent with recent reports highlighting the potential of AI-assisted systems to improve diagnostic standardization, radiographic interpretation, and clinical decision-making in dentistry.^[28, 40] Despite these advantages, soft tissue assessment was identified as the least reliable aspect of AI interpretation by 45.1% of respondents, suggesting that current AI systems are more effective at hard-tissue analysis than at soft-tissue evaluation.

Regarding clinical outcomes, the most frequently observed benefit of AI implementation was a reduction in intraoperative surprises and procedural errors (34.9%), followed by improved ridge width maintenance (24.9%). Overall, the findings indicate that AI is increasingly perceived as a valuable adjunctive technology that can enhance diagnostic accuracy and treatment planning. However, further validation is required before widespread evidence-based implementation can be achieved.^[28, 40, 41, 42]

Table 8. Artificial intelligence integration in diagnostics and planning.

Question (Primary Response)	Category	Frequency (n)	Percentage (%)
Primary AI tool used	CBCT segmentation only	165	40.2%
	Caries / bone-loss detection only	102	24.9%
	Both CBCT segmentation and caries detection	82	20.0%
	Nerve / anatomical landmark detection only	41	10.0%
	No AI tools used	20	4.9%
Primary diagnostic information AI provided	Precise defect dimensions (W/H/D)	143	34.9%
	Buccal plate thickness estimation	102	24.9%
	Optimal graft volume prediction	62	15.1%
	Soft-tissue biotype inference	41	10.0%
	None/other single primary benefit	62	15.1%
AI effect on defect classification accuracy	Significantly improved	164	40.0%
	Moderately improved	123	30.0%
	Slightly improved	82	20.0%
	No change	41	10.0%
	Soft-tissue assessment	185	45.1%
Area considered least reliable in AI interpretation	Early lesion / cystic pathology detection	102	24.9%
	Bone density estimation (over/underestimation)	62	15.1%
	Landmark detection errors	41	10.0%
	No reliability concerns	20	4.9%
	Reduced intraoperative surprises/errors	143	34.9%
The primary observed change in treatment outcomes after AI	Improved ridge width maintenance	102	24.9%
	Better membrane/graft selection	62	15.1%
	No significant outcome change	62	15.1%
	Other improvements (efficiency, documentation)	41	10.0%

Satisfaction and clinical efficiency

The survey also explored clinicians' perceptions regarding treatment satisfaction and clinical efficiency associated with ridge preservation, guided bone regeneration (GBR), biologic adjuncts, soft tissue augmentation, and AI-assisted workflows. Participants were asked to evaluate the perceived impact of these approaches on treatment predictability, workflow efficiency, and overall satisfaction with clinical outcomes. Most respondents reported favorable perceptions regarding the use of regenerative procedures in implant dentistry. Clinicians generally agreed that ridge preservation and GBR improve treatment planning and facilitate implant site development. Similarly, biologic adjuncts and soft tissue augmentation procedures were perceived as valuable tools for enhancing tissue management and optimizing

esthetic outcomes.^[34, 43] The results shown in Table 9 demonstrate high levels of clinician-reported patient satisfaction and perceived improvements in clinical efficiency following regenerative procedures. Overall, 41.9% of respondents reported that patients were "very satisfied" with treatment outcomes. In comparison, 33.7% of patients reported being "satisfied," indicating that more than three-quarters of clinicians perceived favorable patient responses to regenerative therapies. Reduced chairside treatment time was the most frequently reported improvement in clinical efficiency (37.6%), followed by fewer intraoperative complications (31.2%) and a more streamlined clinical workflow requiring fewer patient visits (20.0%). Accurate defect assessment and treatment planning were considered the most important contributors to successful regenerative outcomes (41.0%),

emphasizing the critical role of comprehensive preoperative evaluation. Other influential factors included the selection of appropriate graft materials and biologic agents (28.3%) and surgical technique and flap management (20.0%). These observations are consistent with previous evidence indicating that treatment planning, regenerative biomaterials, and meticulous surgical execution are key determinants of successful regenerative outcomes.^[29, 34, 43] Despite generally positive outcomes, clinicians identified soft-tissue handling

and flap tension management as the primary limitations of current regenerative workflows (35.6%), followed by the cost and availability of biologic or graft materials (27.3%). These findings suggest that regenerative therapies are associated with high levels of satisfaction and improved clinical efficiency; however, optimizing soft tissue management and reducing economic barriers remain important areas for future improvement.^[29, 31, 34, 43]

Table 9. Satisfaction and clinical efficiency of the respondents.

Primary Response	Category	Frequency (n)	Percentage (%)
Observed patient satisfaction after regenerative procedures	Very satisfied	172	41.9%
	Satisfied	138	33.7%
	Neutral	62	15.1%
	Dissatisfied	28	6.8%
	Very dissatisfied	10	2.4%
Primary clinical efficiency improvement observed	Reduced chair time	154	37.6%
	Fewer intraoperative complications	128	31.2%
	Streamlined workflow/fewer visits	82	20.0%
	Improved graft handling/material use	46	11.2%
The most important factor contributing to successful regenerative outcomes	Proper defect assessment & planning	168	41.0%
	Choice of graft material/biologics	116	28.3%
	Surgical technique & flap management	82	20.0%
	Patient's systemic health & compliance	44	10.7%
Primary limitation in the current bone/soft tissue regeneration workflow	Soft-tissue handling/flap tension issues	146	35.6%
	Biologic/graft material cost or availability	112	27.3%
	Imaging/measurement limitations	92	22.4%
	Postoperative patient compliance	60	14.7%

4. Discussion

The present cross-sectional survey explored clinicians' perspectives regarding ridge preservation, guided bone regeneration (GBR), biologic adjuncts, soft tissue augmentation, and the emerging role of artificial intelligence (AI) in regenerative and implant dentistry. The findings indicate that these approaches are widely recognized by clinicians as important components of contemporary implant therapy and are perceived to contribute positively to treatment planning, tissue management, and clinical workflow. Regarding ridge preservation, most participants emphasized the importance of maintaining alveolar ridge dimensions following tooth extraction. This observation is in agreement with previous systematic reviews demonstrating that alveolar ridge preservation can reduce post-extraction dimensional changes and facilitate future implant placement.^[34] Nevertheless, because the present study was survey-based, the findings represent clinicians' perceptions

and do not provide direct evidence regarding the clinical effectiveness of specific ridge preservation protocols. Similarly, clinicians reported favorable perceptions of GBR procedures, particularly regarding implant site development and bone volume maintenance. Most clinicians perceived GBR as a predictable and effective treatment modality.^[44] However, the current survey did not directly evaluate clinical outcomes; therefore, these findings should be interpreted as reflecting professional experience and treatment preferences rather than objective therapeutic success. Respondents also viewed the use of biologic adjuncts positively. Platelet concentrates and enamel matrix derivatives were frequently perceived as beneficial for enhancing wound healing and supporting tissue regeneration. These observations are consistent with the growing body of evidence suggesting that biologic agents may improve soft tissue healing and regenerative processes. However, the magnitude of their clinical benefit remains dependent on case

selection and treatment protocols.^[36, 37] Soft tissue augmentation emerged as another important aspect of regenerative implant therapy. Respondents generally considered adequate peri-implant soft tissue volume and keratinized tissue width essential for achieving stable esthetic and functional outcomes. Contemporary evidence supports the role of soft-tissue augmentation in improving peri-implant tissue stability and esthetics, although clinical outcomes may vary depending on surgical technique and patient-related factors.^[35] An important finding of this study relates to the growing interest in AI-assisted technologies. Most clinicians expressed positive attitudes toward the use of AI for radiographic interpretation, treatment planning, and clinical decision support. Recent developments in dental AI have demonstrated promising applications in image analysis and diagnostic assistance.^[28, 41]

Nevertheless, the present survey assessed clinicians' perceptions only and did not investigate the actual diagnostic accuracy, reliability, or clinical performance of AI systems. Consequently, additional prospective and clinical studies are needed to validate the practical benefits of AI-assisted approaches in regenerative dentistry. This study has several limitations. First, the findings are based on clinicians' self-reported perceptions and may be influenced by individual experiences and professional preferences. Second, the cross-sectional design does not allow causal inferences regarding treatment effectiveness. Finally, the study did not evaluate patient-level clinical outcomes; therefore, the findings should be interpreted as reflecting current clinical perceptions and practice patterns rather than objective treatment efficacy. Despite these limitations, the present survey provides valuable insights into clinicians' perspectives on regenerative implant therapies. It highlights current trends in integrating biologics, soft-tissue augmentation, and AI-assisted diagnostics into contemporary clinical practice.

5. Conclusion

This cross-sectional survey demonstrated that clinicians generally hold positive perceptions regarding ridge preservation, guided bone regeneration, biologic adjuncts, and soft tissue augmentation in regenerative implant dentistry. Most respondents considered these approaches valuable components of contemporary implant therapy and reported favorable experiences regarding their clinical application. Furthermore, the findings indicate a growing interest in digital workflows and AI-assisted diagnostic technologies, reflecting the ongoing transformation of regenerative implant practice. However, the present findings represent clinicians' perceptions and self-reported experiences rather than direct patient-level clinical outcomes. Future studies incorporating prospective clinical designs and objective outcome assessments are warranted to evaluate further the effectiveness and long-term impact of these regenerative approaches and emerging digital technologies.

Conflict of Interest

The authors declared that there is no conflict of interest.

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