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STUDY AND EVALUATION OF COLLAGEN MATRIX FOR GINGIVAL VOLUME AUGMENTATION USING 3D MODELING

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Introductio

Reconstructive surgery of the jawbones is currently one of the key approaches in restoring the continuity of the dental arch [1]. This is particularly relevant for patients with long-term edentulism, where significant loss of bone tissue leads to a decrease in gingival volume, complicating the achievement of optimal functional and aesthetic outcomes [2]. Problems associated with marginal periodontal soft tissues may lead to complications in implantation such as gingival hyperplasia or postoperative recession [3], as well as peri-implantitis with associated bone resorption around the implant neck [4].

Among all augmentation methods, the "gold standard" is the transplantation of a connective tissue graft (CTG) [5]. However, this technique has several drawbacks, including pain syndrome, the necessity of repeated surgeries for donor tissue harvesting, and limited tissue volume [6].

An alternative approach to increasing the volume of attached keratinized gingiva involves the use of porcine collagen-based materials, among which the three-dimensional collagen matrix Mucograft is of particular interest. It features a combined structure and promotes soft tissue regeneration in a single procedure.

Aim of the Study

Experimental evaluation of the effects of collagen matrix on gingival soft tissue regeneration using 3D modeling.

Materials and Methods

Miniature ponies aged two years, weighing 25–45 kg with fully developed occlusion were selected as optimal biomodels. Considering individual anatomical

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variability, animals with visually similar gingival morphology were chosen. The experimental study consisted of three surgical phases.

Biomaterials for Tissue Regeneration

Geistlich Bio- Geistlich Bio-Oss ®

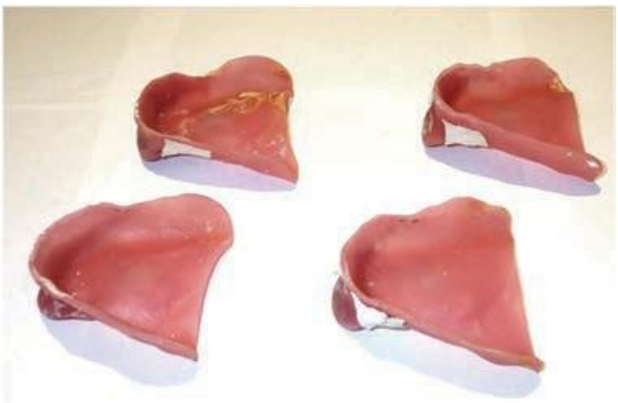
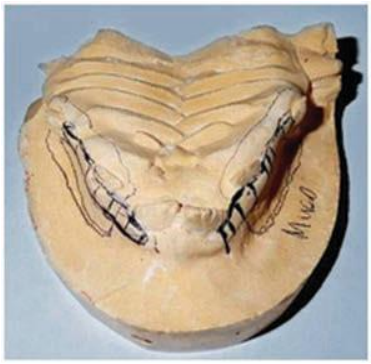
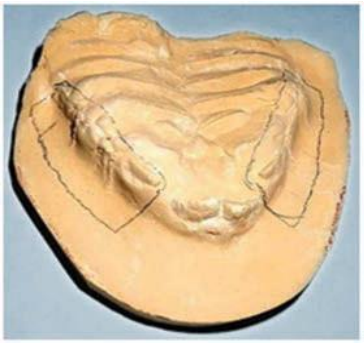
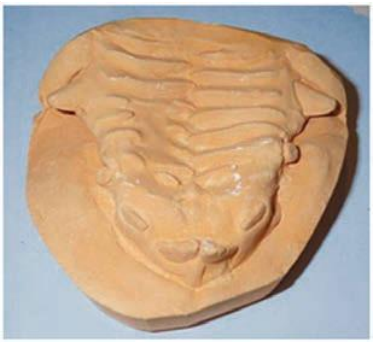


Figure 1. Individually fabricated impression trays







a **b**

c

a — before first stage, b — before second stage, c — before third stage.

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Figure 2. Measurement areas on plaster models at different experimental stages:

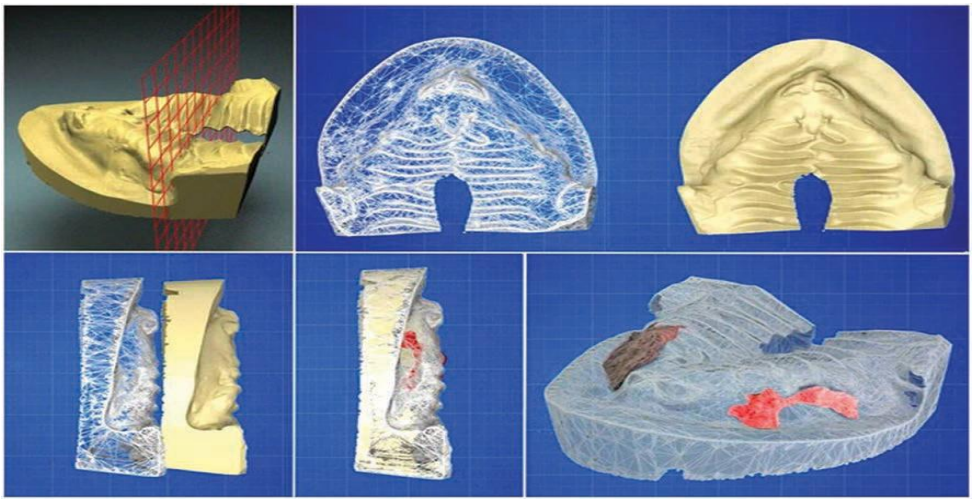


Fig 3. Plaster impression scanning stagesure

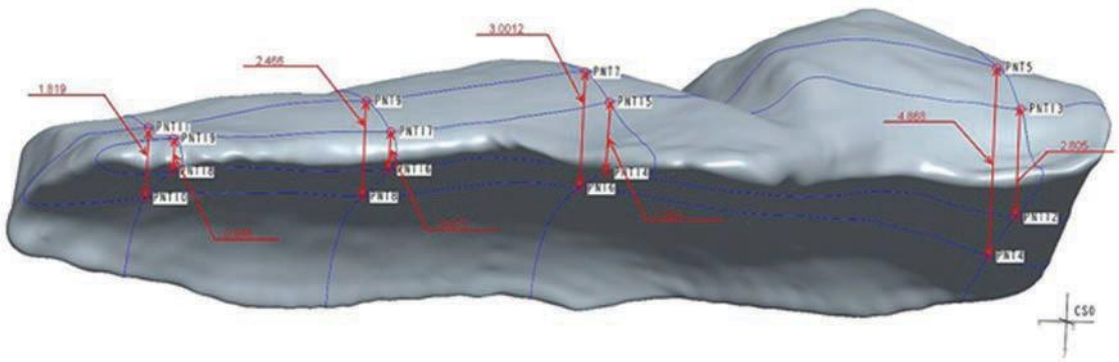
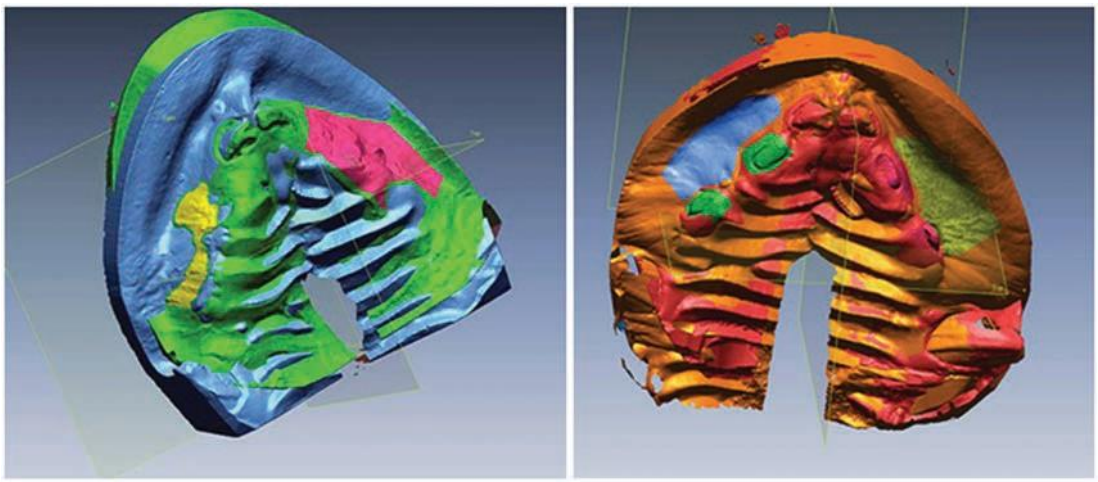


Figure 4. Comparison of 3D models using reference points



a **b**

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Figure 5. Examples of 3D models:
a — animal No.1; b — animal No.2

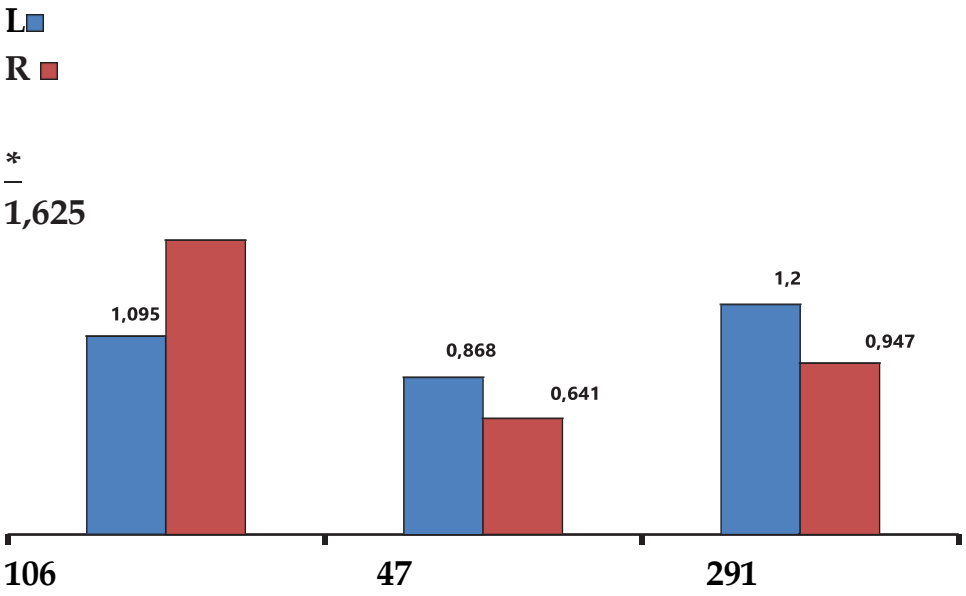

Figure 6. Gingival soft tissue volume increase post-transplantation (Mucograft and CTG) based on 3D modeling data
L — left side; R — right side

In the first phase, the thickness of the attached gingiva was measured at eight points on each side using an endodontic plugger with a rubber stopper and an endodontic ruler. During the surgery, two teeth were extracted with elevators and forceps. Bone beds were prepared and intrabony screw-type dental implants were placed.

On the right maxilla, bone defects were restored using Bio-Oss graft and covered with a 30×40 mm Bio-Gide collagen membrane. On the left maxilla, defects were filled with autogenous bone chips and covered similarly.

In the second phase, the implants were uncovered and healing abutments were placed. A mid-crestal incision was made bilaterally. On the left side, a full-thickness connective tissue graft was placed and secured. On the right side, a trapezoidal mucosal flap was prepared, split, and apically repositioned with periosteal fixation, preserving about 1.0–1.5 mm of attached keratinized mucosa. A 20×30 mm dry Mucograft matrix was trimmed and implanted, and the flap was sutured.

This study marked the first time Mucograft was implanted post-dental implantation in an open manner, allowing for secondary intention healing.

In the third phase, the animals were euthanized via intramuscular administration of Listenen. Gingival impressions were taken before each phase

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using custom light-cured trays (Vertex Light Curing Trayplates) and Kromopan 100 Type 1 alginate.

Plaster models were made from the impressions. The boundary between attached and free mucosa was visible, allowing measurement of mucosal attachment width with calipers (Fig. 2). Models were scanned using a Roland LPX-250 3D laser scanner, and the data was processed in Rapid Form 2006 (INUS Technology, South Korea).

Results

Soft tissue augmentation was evaluated using 3D scans of the impressions taken at each stage (Fig. 3). Alignment was achieved using reference points and surface matching. Three mutually perpendicular planes—median-sagittal, horizontal, and frontal—were set up for coordinate orientation (Fig. 4).

Three sets of impressions per animal allowed for calculation of tissue volume gain in the operated region (cm^3) (Fig. 5). Using rank dispersion analysis and Tukey's test, no significant difference in tissue volume gain was observed between Mucograft and CTG ($p=0.979$), except in animal No. 1 where Mucograft led to a significantly greater volume increase compared to animal No. 2 (Table 1).

Volume increase in the right gingiva may be associated with inflammation-induced edema seen in animal No. 1 after 77 days post-op and 35 days post-transplantation. Animals No. 2 and No. 3 showed less inflammation after 45 days post-transplantation.

Greater connective tissue content in animal No. 3 correlated with slightly more volume gain than in animal No. 2. Average gingival volume increase was 0.8±0.1 cm^3 after Mucograft transplantation and 1.1±0.12 cm^3 after CTG, with no statistically significant difference ($p=0.118$).

Hence, Mucograft transplantation increased gingival width and soft tissue volume, with changes comparable to CTG outcomes.

Table 1. Gingival Soft Tissue Volume Gain (cm^3) via 3D Modeling (Mean±SD)

Animal No.	CTG	Mucograft
1	1.1±0.1	1.6±0.2*
2	0.9±0.2	0.6±0.1*
3	1.3±0.1	0.9±0.1

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Average	1.1±0.12	0.8±0.1
*Statistically significant differences ($p<0.05$, Tukey's test).		

These changes were observed under gingival remodeling conditions following mechanical trauma and implant placement, accompanied by reactive inflammation.

Conclusion

Long-term success of dental implants is largely dependent on the volume of attached keratinized gingiva, as inadequate width increases the risk of trauma, plaque accumulation, and inflammation.

This study aimed to improve surgical techniques for augmenting keratinized gingiva using Mucograft in experimental settings.

The experimental stage showed that, after relatively short intervals between surgeries (35 days post-Mucograft or CTG transplantation, 42 days after initial surgery), both bone and soft tissue remodeling occurred. Findings included edema, inflammation, mucosal thickening, and peri-implantitis.

Reliable assessment of gingival tissue repair requires precise measurement techniques. Conventional width and thickness assessments provide only localized data, whereas 3D facial and dental imaging offers a comprehensive evaluation.

For the first time in an experimental study, we evaluated gingival volume using 3D modeling. Volume increase averaged 0.8±0.1 cm^3 with Mucograft and 1.1±0.12 cm^3 with CTG, showing no significant difference.

Thus, Mucograft transplantation in post-surgical settings achieved comparable gingival width and volume augmentation to CTG. Notably, the matrix was applied superficially—contrasting previous experimental studies that embedded it within soft tissues.

Due to inflammation from surgical trauma (tooth extraction, implantation, matrix transplantation), graft resorption occurred. Despite this, Mucograft showed promising results under open application conditions, suggesting effective use in clinical settings.

Mucograft's combined structure facilitates vascular ingrowth, enabling single-stage soft tissue defect repair even with limited soft tissue availability. However, comparative studies of Mucograft use in different anatomical zones remain lacking.

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