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· 临床研究 ·

口内焊接辅助渐进式加压技术应用于前牙种植桥体软组织塑形的美学效果

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【摘要】　目的　探讨口内焊接支架联合卵圆形桥体渐进式加压技术对种植体支持式固定修复体（implant-supported fixed dental prostheses，ISFDPs）软组织美学轮廓的塑形效果。**方法**　获得本院医学伦理审查委员会审批，回顾性选取2022年8月至2024年3月于本院就诊行3~5单位种植修复的前牙区连续缺牙患者32例（男20例，女12例，年龄40~68岁）。采用口内焊接技术制作临时修复体钛支架，并通过螺丝固位实现精准被动就位；将桥体整塑为卵圆形，在桥体组织面选择性添加0.8~1 mm厚度的流动树脂，同时避免组织缺血，每4周复诊1次，视需要调整2~3次，使桥体牙对应的软组织形成一个深约3 mm，颊舌向曲率半径为2.5~3.0 mm的卵圆窝，进行软组织渐进式加压塑形，永久修复完成后，随访观察1年以上。评价指标包括：机械并发症、红色美学指数（pink esthetic score，PES）、牙龈乳头指数（papilla index score，PIS）以及患者满意度的视觉模拟评分（visual analogue scale，VAS）。**结果**　32例病例随访期间未见螺丝松动或修复体折裂等机械并发症；软组织美学效果理想，PES总分平均为（11.97 ± 1.18）分，96.9%的病例 ≥ 8分；PIS显示93.5%的邻间隙达理想充盈状态；VAS评分显示90.6%患者对修复效果满意。**结论**　口内焊接支架联合卵圆形桥体渐进式加压塑形技术可精准塑造符合生理形态的软组织轮廓，实现理想的美学效果。

【关键词】　前牙区；　种植牙美学；　红色美学指数；　牙龈乳头指数；　软组织塑形；　口内焊接；　卵圆形桥体；　螺丝固位；　渐进式加压

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Aesthetic outcomes of intraoral welding with progressive compression for soft tissue contouring of implant bridge pontics in anterior teeth

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【Abstract】　Objective　To evaluate the shaping effect of the intraoral welding framework combined with the progressive pressure technique using an ovate pontic on the soft tissue aesthetic contour of implant-supported fixed dental prostheses (ISFDPs). **Methods**　The Medical Ethics Review Committee of this hospital approved this retrospective study, which was conducted on 32 patients with consecutive partial edentulous in the anterior teeth (20 males, 12 females, aged 40 - 68 years) who received 3- to 5-unit ISFDPs between August 2022 and March 2024. Titanium frameworks for provisional prostheses were fabricated using the intraoral welding technique and screw-retained to achieve precise passive fit. The pontics were designed into an ovate shape. A progressive pressure technique was applied by selectively adding 0.8 - 1 mm thick flowable resin to the tissue surface of the pontic, while ensuring the avoidance of tissue blanching. Patients have a follow-up visit every 4 weeks, and the pontics were adjusted 2 - 3 times as needed, to form an ovate socket in the corresponding soft tissue approximately 3 mm in depth and 2.5 - 3.0 mm in buccolingual curvature.

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Definitive restorations were delivered after the conditioning period, and patients were followed up for over 1 year. Outcome measures included mechanical complications, Pink Esthetic Score (PES), Papilla Index Score (PIS), and patient satisfaction assessed using a Visual Analogue Scale (VAS). **Results** During the follow-up period, no mechanical complications such as screw loosening or prosthesis fracture were observed in the 32 cases. The soft tissue aesthetic outcomes were favorable, with a mean total PES of 11.97 ± 1.18, and 96.9% of the cases achieving a score ≥ 8. According to the PIS, 93.5% of the proximal sites exhibited ideal papilla fill. VAS results indicated that 90.6% of patients were satisfied with the restorative outcome. **Conclusion** The technique combining an intraoral welding framework with progressive pressure using an ovate pontic can precisely shape the peri-implant soft tissue contour to mimic physiological morphology, achieving an ideal aesthetic outcome.

【**Key words**】 anterior teeth region; dental implant aesthetics; pink esthetic score; papilla index score; soft tissue contouring; intraoral welding; ovate pontic; screw-retained; progressive compression

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随着口腔种植技术的快速发展与临床应用的日益成熟,种植体周围软组织的形态及美学受到临床医师的广泛关注。理想的软组织形态不仅影响美学效果,还与种植体的长期稳定性密切相关[1]。种植临时修复体可通过修复体组织面实施增量式树脂堆塑与渐进式加压技术[2],诱导软组织轮廓成形及龈乳头形态改建,该过程称为个性化牙龈塑形[3]。传统的临时修复方法在软组织塑形方面存在一定的局限性,如压力分布不均、难以实现精准调控等。近年来,口内焊接技术逐渐应用于种植修复领域[4],其刚性钛支架结构以及纵向固位螺丝的精准被动就位为软组织塑形提供了新的可能性。

口内焊接技术于1982年由Mondani等[5]首次提出,旨在口内将种植体上部配件与个性化弯制的钛丝焊接成一整体支架,实现修复体精准被动就位,并增强修复体的强度[6]。机械稳定性与被动就位协同优化,这一特性与卵圆形桥体的渐进式加压技术相结合,可避免因修复体就位不良导致的局部应力集中,从而降低种植体周围骨吸收的风险[7]。同时,口内焊接制作的修复体因其精准被动就位和刚性结构[8],能够确保卵圆形桥体施加的压力均匀传递至软组织,从而促进更稳定、更美观的龈缘形态。但口内焊接辅助渐进式加压技术应用于种植桥体软组织塑形的临床报道较少,本文回顾性分析32例接受3~5单位种植修复的前牙区连续缺牙患者,探讨应用口内焊接技术与渐进式牙龈加压塑形技术进行软组织塑形的美学效果,以期为临床实践提供参考依据。

1 资料和方法

1.1 研究对象

回顾性分析2022年8月至2024年3月于湛江南方口腔医院就诊行3~5单位种植修复的前牙区连续缺牙患者32例,其中男20例,女12例,患者年龄40~68岁,完成永久修复并随访观察1年以上。本研究经过本院医学伦理审查委员会审批(审批号:2022081208),所有患者知情同意并自愿签署知情同意书。

纳入标准:①无系统性疾病;②非吸烟者或轻度吸烟者(≤10支/d);③无活动性牙周炎症;④邻牙无严重倾斜或松动,咬合关系正常;⑤术前需通过沟通确认患者对修复效果的预期符合临床可实现范围;⑥前牙区3~5颗牙连续缺失完成种植修复1年及以上。

排除标准:①存在系统性疾病;②重度吸烟者(>10支/d)或有咀嚼槟榔等不良习惯者;③存在未经治疗的邻牙牙周病或根尖周病变;④缺牙区存在严重骨缺损或软组织量明显不足;⑤妊娠期或哺乳期妇女;⑥缺失牙数超过5颗、非连续缺失或为游离端的复杂病例,以及随访资料不完整或失访患者。

1.2 样本量计算

本研究样本量使用PASS 2021软件进行计算。以主要评价指标红色美学指数(pink esthetic score, PES)为依据,参考Puisys等[9]学者在美学区

种植的前瞻性研究结果，预设PES均值为11.30±1.32。为检验与临床基线值（预设为8.0分）差异是否具有统计学意义，设定检验效能（1-β）为0.8，α=0.05（单侧），计算得出所需总样本量为28例。为进一步控制失访风险，最终将样本量扩大至32例。该样本量旨在验证该技术能否使PES稳定达到临床可接受水平（≥8分）。

1.3　术前准备

患者术前均接受临床检查，拍摄锥形束CT（cone beam computed tomography，CBCT），取模获得口内模型，并拍摄术前口内及面像照片。基于检查结果确定治疗方案，患者签署知情同意书。患者均接受系统性牙周基础治疗。

1.4　治疗过程

1.4.1　植入种植体　患者均植入Ankylos种植体共78颗。植入过程中均实现良好的初期稳定性［植入扭矩35 N·cm，种植体稳定系数（implant stability quotient，ISQ）值>70］。其中即刻种植组18例（56.3%）；延期种植组14例（43.7%），在拔牙创愈合3~6个月后植入。

1.4.2　口内焊接钛支架并制作临时修复体　在种植体上安装适配的临时基台，弯制直径2.0 mm的钛丝，使其与种植体上方的临时基台贴合。使用口内焊接仪（WeldOne CD-500，CMP Industries，美国），将铜电极钳对称夹持于钛丝与基台两侧进行焊接[10-11]。主体钛支架焊接完成后，额外焊接固位钛丝以增强临时修复体的固位性能。随后将焊接完成的钛支架取出，清洁消毒后均匀涂布光固化遮色树脂（OMNI Opaquer，Kerr Corporation，美国）。将钛支架重新置于口内，通过开窗式转移杆定位临时牙模具，注入临时树脂材料（Delizin™ 双糊剂套装，Zhermack S.p.A，意大利），光固化后取出，在口外进行调磨和精修，并对穿龈袖口及桥体龈端进行高度抛光。

1.4.3　软组织渐进式加压塑形过程　种植手术当日，对符合即刻负载条件的病例，通过口内焊接支架制作临时修复体，期间注意避免临时修复体对牙龈造成压迫，影响创口愈合。对于非即刻负载病例，则采用埋入式愈合方式，3个月后种植体完成初期骨结合[12]，进入牙龈塑形阶段。取出临时修复体，将桥体整塑为卵圆形。观察穿龈袖口和桥体牙软组织的轮廓，在桥体组织面选择性添加0.8~1 mm厚度的流动树脂Filtek™ Supreme Flowable（F3858，3M，美国）。此阶段固位螺丝扭力值为35 N·cm，通过缺血性反应测试验证压力安全性，即受压发白的牙龈在15 min内恢复正常血色为标准[13]。每4周复诊1次，视需要调整2~3次，目标是使桥体牙对应的软组织形成1个深约3 mm，颊舌向曲率半径为2.5~3.0 mm的卵圆窝，最终使种植体周围软组织的颜色、形态、丰满度与邻牙及对侧牙协调一致。

1.4.4　完成最终修复　牙龈塑形完成后，待软组织稳定至少1个月，确保穿龈轮廓和龈乳头形态理想，即可进行永久修复体的制作与戴入。佩戴最终修复体后，拍摄X线片或CBCT确认修复体就位情况及种植体周围骨水平，建立基线资料以供长期随访对比。

1.5　评价指标

1.5.1　机械并发症　考察修复体中央螺丝稳定性与修复体完整性。

1.5.2　红色美学指数（PES）[14]　PES通过7项核心指标量化种植修复体周围软组织美学：①近中龈乳头（2分：完全充盈邻间隙，无“黑三角”；1分：部分缺损或高度不足；0分：完全缺失）；②远中龈乳头（评分标准同近中）；③边缘龈水平（2分：与对照牙平齐，差异≤1 mm；1分：不齐但差异≤1 mm；0分：差异>1 mm）；④牙龈边缘形态（2分：形态流畅，与对照牙协调；1分：轻微不协调；0分：明显不协调）；⑤牙槽突外形（2分：外形丰满协调；1分：稍有凹陷；0分：明显凹陷）；⑥牙龈色泽与质地（2分：颜色、质地、点彩正常；1分：轻微改变；0分：明显炎症/苍白/瘢痕）；⑦牙龈曲线（2分：与邻牙和谐延续；1分：轻微不协调；0分：严重不协调）。每项评分0~2分，总分14分，达标率根据以下标准计算：① PES总分：以修复体为单位统计，得分≥8分视为达标；②各单项指标：以位点为单位统计，得分≥1分视为达标。计算公式：达标率=（达标样本数/总样本数）× 100%[15-16]。

1.5.3　牙龈乳头指数（PIS）[17]　PIS用于评估桥体间龈乳头充盈度，在种植修复的美学与功能评估中，牙龈乳头指数是衡量种植体周软组织健康状况及美学效果的关键指标，客观反映种植体周组织的生物学适应性和美学稳定性，其评价包含5个等级[18]（0：牙龈乳头完全缺失；1：牙龈乳头部分充盈，但未达到邻间隙高度的1/2；2：牙龈乳头充盈并超过邻间隙高度的1/2；3：牙龈乳头完全充盈，达到邻接点水平；4：牙龈乳头过度充盈，超出邻接点水平）。

1.5.4　视觉模拟评分（visual analogue scale，VAS）　患者的主观满意度通过VAS进行衡量[19]，收集患者对修复体整体效果、美观度、舒适度及功能满意度的直接反馈。VAS量表为一条长度为10 cm的水平直线，两端分别代表"极度不满意"（0分）和"非常满意"（10分）。患者根据自身感受，在直线上标记相应位置，研究人员测量"0"点至标记点的距离作为评分，数值越高代表满意度越高。

1.6　统计学方法

使用SPSS 26.0进行数据分析。计量资料采用均数±标准差表示，计数资料采用例数（百分比）表示。所有定量数据均经过Shapiro-Wilk检验符合正态分布，组间比较采用t检验，相关性分析采用Pearson相关分析。P<0.05为差异具有统计学意义。

2　结　果

2.1　机械并发症

在随访期内，32例病例均未发生任何机械并发症，包括螺丝松动及修复体折裂。

2.2　红色美学指数（PES）评价

如表1所示，32例修复体的PES总分平均为（11.97 ± 1.18）分，96.9%的病例≥8分，表明其周围软组织获得了良好的美学形态。

表1　32例前牙列缺损患者行种植支持式固定修复后红色美学指数评分结果

Table 1　Pink esthetic score outcomes of implant-supported fixed dental prostheses in 32 patients with anterior teeth partial edentulism　$\bar{x}±s$，n=32

Evaluation criteria	Score of PES	Pass rate (%)
Mesial papilla	1.93 ± 0.26	93.5
Distal papilla	1.93 ± 0.28	93.5
Level of mucosal margin	1.65 ± 0.55	87.5
Curvature of mucosal margin	1.58 ± 0.60	84.4
Alveolar process deficiency	1.45 ± 0.65	78.1
Gingival color and texture	1.75 ± 0.47	90.6
Gingival contour	1.68 ± 0.52	87.5
Mean total PES (maximum 14 points)	11.97 ± 1.18	96.9

① for the total PES score, a prosthesis was considered a pass if the score was ≥ 8 points; ② for individual criteria, a site was considered a pass if the score was ≥ 1 point. The pass rate = (Number of passing samples / Total number of samples) × 100%

2.3　牙龈乳头指数（PIS）评价

如表2所示，32例病例中，93.5%（86/92）的邻间隙达到理想充盈状态（PIS-3级），显著降低龈乳头缺损风险。

表2　32例前牙列缺损患者行种植支持式固定修复体后牙龈乳头指数评价结果

Table 2　Papilla index score assessment of implant-supported fixed dental prostheses in 32 patients with anterior teeth partial edentulism　n (%)

Grade	Characteristic clinical features	Proximal sites
0(Absence)	No papillary structure	0(0.0)
1(Incomplete fill)	None observed	0(0.0)
2(Deficient papilla fill)	Collapsed morphology (without bleeding)	6(6.5)
3(Complete papilla fill)	Tapered papillary contour, symmetrical with no black triangle	86(93.5)
4(Hyperplastic)	None observed	0(0.0)

Assessment based on 32 implant-supported fixed prostheses (3 – 5 units), totaling 92 proximal sites

2.4　视觉模拟评分（VAS）评价

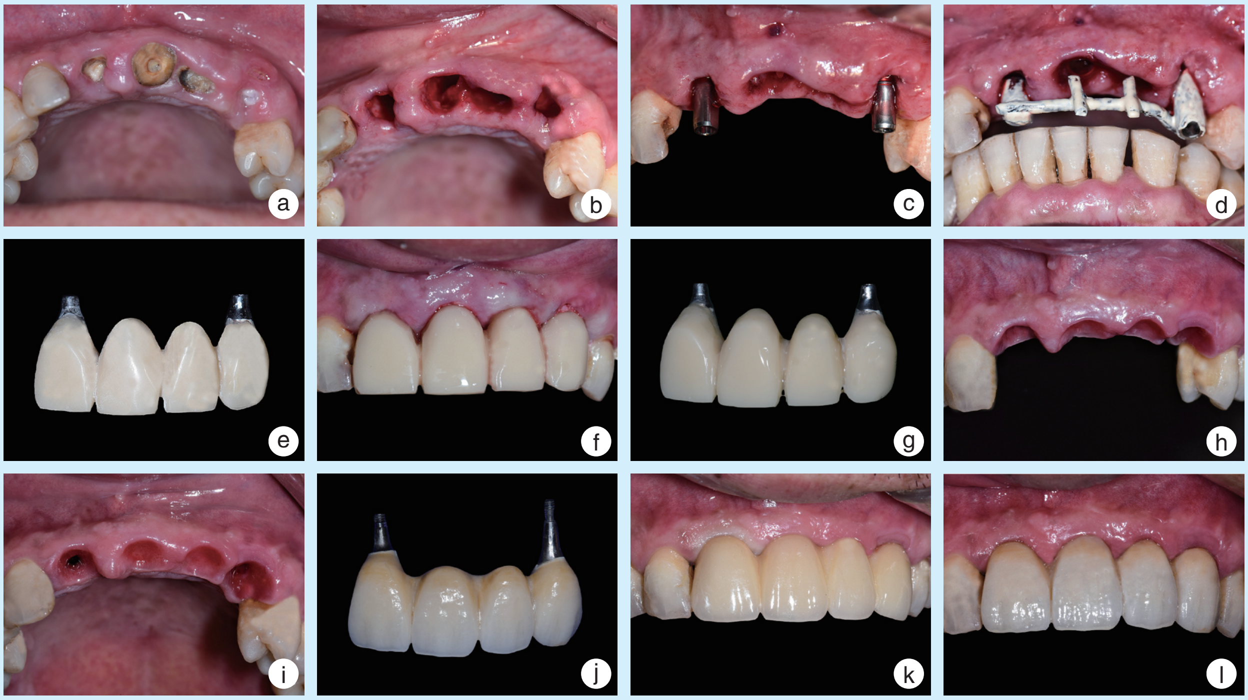
90.6%（29/32）的患者对修复效果表示"满意"或"非常满意"（VAS≥7分），VAS评分均值为8.4±1.1；其中3例治疗未达预期效果的患者中，2例患者主诉咬合不适（VAS=6分）；1例患者认为颌面美学协调性欠佳（VAS=5分）。

3　典型病例

患者，男性，56岁。主诉：上前牙缺损数年，影响咀嚼功能及美观。口内检查示：12、11、21、22牙位可见残留牙根，缺牙区牙槽嵴轮廓平整，软组织形态及质地良好。CBCT检查证实上述牙位仅存残根，牙冠缺失。诊断：上颌牙列缺损（12、11、21、22残根）。经患者知情同意，拟定治疗方案：拔除残根后，于12、22位点行种植体支持式固定修复，并采用口内焊接技术制作螺丝固位即刻临时修复体，诱导软组织塑形，最终完成永久修复。

治疗过程：先行全口系统性牙周治疗，控制炎症4周后，微创拔除12、11、21、22残根并彻底清创。随后于12、22位点分别植入Ankylos种植体（3.5 mm×11 mm），植入扭矩35 N·cm，初期稳定性良好。安装临时基台，采用口内焊接技术将直径2 mm钛条与临时基台连接为刚性支架，涂布遮色树脂，于口外制作卵圆形桥体的复合树脂临时修复体。在种植体周围跳跃间隙及骨缺损区植入低替代速率骨移植材料。戴入临时修复体，调整咬合，初步塑造软组织轮廓。3个月后取出修复体，于桥体龈端添加1 mm树脂以扩大穿龈轮廓，重新戴入实施二次塑形。4周后复诊见软组织形态初

步形成，再次添加树脂精细调整。继续塑形4周后，软组织形态稳定，呈现理想扇贝状穿龈轮廓。采用口内扫描仪采集戴有个性化转移杆的口内三维数据，精准记录经塑形后稳定的牙龈轮廓。在设计软件中，将该数据与临时修复体的扫描文件进行拟合，构建出一个包含种植体位置、理想的牙龈形态及已验证的美学轮廓的复合数字模型。最终基于该整合数据完成氧化锆终修复体的设计与制作。戴入后可见龈端过渡自然、贴合紧密。修复后1年复查显示，种植体周围软组织健康稳定，龈乳头充盈度显著改善，红色美学效果理想，患者对功能与美学效果满意(图1)。



a: preoperative intraoral view showing residual roots at sites 12, 11, 21, and 22. The alveolar ridge exhibits a generally flat contour with acceptable soft tissue conditions. b: minimally invasive extraction of the residual roots at sites 12, 11, 21, and 22 was performed, followed by thorough debridement and preservation of the labial bone plate and inter-proximal alveolar ridge height. c: two implants were placed at sites 12 and 22, demonstrating good primary stability and adequate insertion torque. Three-dimensional implant positioning satisfied both aesthetic and functional requirements. d: an intraoral welded titanium framework was fabricated to splint the two implants rigidly, followed by an application of resin-based opaque ceramic to mask the metallic color. e: an ovate pontic design composite resin provisional prosthesis was fabricated based on the titanium framework intraorally, simulating the natural tooth emergence profile to provide initial gingival support. f: the provisional prosthesis was inserted, showing slight blanching of the mucosa under the pontic area, indicating controlled pressure for shaping and guiding soft tissue healing. g: after 3 months of usage, approximately 1 mm of resin was added to the gingival aspect of the pontic to expand the emergence profile and apply secondary pressure for further soft tissue guidance. h and i: following two stages of soft tissue conditioning, a well-defined and stable scalloped contour was formed in the gingival tissue corresponding to the pontic area. j: the definitive prosthesis was fabricated from zirconia, with the gingival contour of the pontic designed according to the matured soft tissue profile. The restoration exhibited natural color and morphology. k: upon insertion of the definitive prosthesis, close adaptation of the gingival margin, smooth transition at the emergence profile, and harmonious aesthetic zone morphology were observed. l: a 1-year follow-up showed healthy and stable peri-implant soft tissue with significantly improved papilla fill and favorable red aesthetic outcomes

Figure 1 A 56-year-old patient with multiple maxillary anterior teeth missing treated with immediate implant restoration using the intraoral welding technique combined with progressive soft tissue sculpting

图1 56岁上颌前牙多牙缺失患者应用口内焊接技术行即刻种植修复联合渐进式软组织塑形

4 讨 论

本研究通过32例连续前牙缺失种植支持式多单位固定桥的临床回顾性研究证实，采用口内焊接支架联合卵圆形桥体渐进式加压技术，可有效实现理想的软组织美学塑形。32例病例随访期间未见螺丝松动或修复体折裂等机械并发症；软组织美学效果理想，PES总分平均为(11.97 ± 1.18)分，96.9%的病例 ≥ 8分；PIS显示93.5%的邻间隙

达理想充盈状态；VAS评分显示90.6%患者对修复效果满意。基于PES-PIS-VAS多维度评价体系的系统评估，验证了该技术的临床价值，表明其修复体形态符合生理性压迫原则，为软组织稳定性提供了关键力学支撑，为临床实践提供了客观依据。

4.1 口内焊接技术与软组织渐进式加压塑形技术的协同效应

口内焊接技术与软组织渐进式加压塑形技术的联合应用，在口腔种植修复领域展现出协同效应。该技术体系通过电阻焊接将多个种植体上部临时基台连接为刚性整体结构，结合纵向螺丝固位方式，实现了修复体的精准被动就位[20-21]。焊接修复体凭借其机械精度，能够实现咬合力的均匀分布，有效避免局部应力集中对骨整合界面的不良影响[22]。焊接制备的一体化钛支架具有界面缺陷少、晶粒结构均质化的特点，其抗疲劳性能因而得到显著提升[23]。钛支架110 GPa的高弹性模量可有效抵抗卵圆形桥体在软组织塑形过程中产生的渐进性压力，防止因修复体形变导致的力学传导异常。有限元分析结果表明，焊接支架结构能够优化应力分布模式，促进种植体的功能性骨结合[24]。在软组织管理方面，该技术体系实现了力学传导的可控性与均匀性。口内焊接钛支架为临时修复体提供稳定的三维支撑，确保其精确就位，同时通过螺丝固位机制实现软组织的渐进式压迫。与传统技术相比，该联合方案具有创伤小、调整灵活等技术特点，结合数字化辅助可进一步提升操作精确度[25]。研究证实，数字化印模联合口内焊接技术可将修复体间隙精确控制在25~40 μm范围内，这一数值显著优于传统铸造修复的(120±35)μm平均水平[26]。采用数字化工作流程[27]，通过个性化转移杆与口内扫描技术，准确记录种植体穿龈袖口形态及桥体龈端形态。整合三维数据与临时修复体扫描信息，实现数字化模型重建，为最终修复体的制作提供重要参考依据[28-29]。对于多单位修复病例，采用计算机辅助设计与制造技术有助于提升修复体精度，减少人为误差，并降低机械并发症的风险[30]。口内-口外联合扫描技术作为一种较传统印模更为精确的数字化手段，能够可靠地将临时修复体在桥体区域创造的理想龈下形态转移至最终的固定修复体上，是实现美学与功能并重的精准修复的重要技术手段[31]。此外，本研究还发现，口内焊接联合渐进式加压技术在4个单位以上桥体修复中展现出显著优势。相较于3单位短桥，多单位桥体跨度更大，修复体就位精度和机械稳定性对软组织塑形的影响更为突出。传统3个单位修复体虽可通过常规粘接或螺丝固位实现一定程度的被动就位，但其刚性不足、易发生微变形，尤其在长跨度情况下难以保证均匀的压力传递[32-33]。而口内焊接技术通过一体化钛支架结构，显著提升修复体刚性，从而为软组织提供持续、均匀的渐进式压力，避免因修复体微动或应力集中导致的软组织缺血或形态不稳定。因此，对于多单位长桥修复，口内焊接技术不仅是一种可行的选择，更应视为确保美学与功能长期稳定的关键技术手段。需要强调的是，临床应用中需严格掌握适应证并规范操作流程，以确保治疗效果的可预期性。

现代种植修复的成功标准不仅要求获得稳定的骨结合，同时需要实现软组织的美学稳定和生理适应性。研究表明，(0.5~0.8)N/cm²的渐进式机械压力通过激活牙龈成纤维细胞的机械敏感通道(如Piezo1通道)，诱导细胞骨架重组和胶原定向排列，为种植修复中软组织美学塑形提供了关键力学参数依据[34-35]。口内焊接钛支架提供刚性力学传导媒介，实现对软组织的可控性压力加载。组织学分析表明，支架的刚性结构通过持续性机械刺激促进了胶原纤维的平行排列，形成自然的扇贝状龈缘形态。研究显示，卵圆形桥体施加的渐进式压力，可通过机械力信号调控机制，促进牙龈成纤维细胞的定向排列和胶原基质重塑，从而形成符合美学要求的生理性牙龈轮廓[36]。值得注意的是，修复体的精确被动就位是确保压力均匀分布的关键因素，咬合力均匀分散至周围软组织，避免局部应力集中，可有效预防局部组织缺血性损伤的发生。

4.2 卵圆形桥体的临床优势与循证依据

卵圆形桥体因其卓越的综合性能已成为种植修复的首选设计方案。在解剖学设计方面，前磨牙区天然牙根的颊舌向曲率半径平均为(2.8±0.3)mm，这一参数为桥体设计提供了重要参考。临床建议采用曲率半径(2.5~3.0)mm的卵圆形桥体底部设计，以引导软组织形成自然的根形突度，这种仿生设计不仅优化了美学效果，同时有利于软组织的长期稳定性[37]。修复体的不良设计是种植体周围炎的重要诱因，在修复设计阶段，确保形成一个利于患者清洁的穿龈轮廓，这是预防种植体周围炎的关键[38]。该设计通过模拟天然牙生理性凸度并与

软组织形成渐进式过渡界面,不仅显著减少了食物滞留风险,其紧密贴合且边缘光滑的特性更使菌斑积聚明显低于改良鞍式桥体。同时,其穿龈轮廓能稳定软组织附着,有效减少微生物定植间隙。这种设计在多牙连续缺失修复中展现出独特优势:功能上,可通过优化咬合力分布提高咀嚼效率;在卫生维护方面,凭借与牙龈轮廓的高度适配,显著降低菌斑滞留;在美学表现上,则能精确仿造天然牙软组织形态,实现"仿生萌出"的自然效果[39]。此外,其与牙槽嵴黏膜的解剖式适配不仅减少食物嵌塞、改善发音功能,还能通过均化机械应力来抑制局部炎症,从而维持软组织的长期健康状态[40]。基于现有临床证据,卵圆形桥体在美观性、自洁性和生物相容性等方面均表现出显著优势,已成为符合适应证病例的首选修复方案。

【**Author contributions**】 Li MY designed the study, performed the experiments, analyzed the data and wrote the article. Huang PS, Huang H analyzed the data, designed the study and revised the article. All authors read and approved the final manuscript as submitted.

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