http://www.zjujournals.com/med
DOI:10.3785/j.issn.1008-9292.2020.02.14

·综 述·

种植前辅助正畸治疗的临床应用研究进展

王诗莹[1,2],顾新华[1]
1. 浙江大学医学院附属第一医院口腔科, 浙江 杭州 310003
2. 浙江大学医学院口腔医学系, 浙江 杭州 310058

[摘 要] 面对复杂的种植病例,单纯的种植术已不能达到理想的治疗目的,各学科联合治疗成为一种趋势。种植前辅助正畸治疗可以为种植修复开辟理想的三维空间,改善患者的咬合关系;充分发挥牙周韧带的生物学潜力,利用正畸牵引刺激自体软硬组织增量;选择适宜时机启动正畸治疗,最大限度地维持种植位点的软硬组织水平,为种植手术及后期修复创造良好条件,进而在功能、美学等方面均可优化种植修复的疗效。本文从种植位点的空间优化、软硬组织增量及种植修复时机选择等方面对种植前辅助正畸治疗进行了综述。

[关键词] 口腔正畸学/治疗; 牙种植; 牙修复; 种植位点; 软硬组织增量; 综述
[中图分类号] R783.5 [文献标志码] A

Progress on clinical application of orthodontic-implant combined therapy

WANG Shiying[1,2], GU Xinhua[1] (*1. Department of Stomatology, the First Affiliated Hospital, Zhejiang University School of Medicine, Hangzhou 310003, China; 2. Department of Stomatology, Zhejiang University School of Medicine, Hangzhou 310058, China*)
Corresponding author: GU Xinhua, E-mail: guxh@zju.edu.cn, https://orcid.org/0000-0001-6674-1803

[**Abstract**] For complex implant cases, simple implantation could not achieve the desired therapeutic effect, and a multidisciplinary approach has become a general trend. Orthodontic treatment before implantation creates favorable conditions for subsequent implantation by increasing restoring three-dimensional space, improving occlusion of patients. It also stimulates the increase of autologous soft and hard tissue while biological potential of periodontal ligament is fully developed. The choice of operation time is vital to keep the level of soft and hard tissue at the implantation site, which improves the curative effect of implantation in terms of function and aesthetics. In this article, the orthodontic-implant combined therapy is briefly reviewed focusing on

收稿日期:2019-10-15 **接受日期**:2019-12-10
基金项目:浙江省自然科学基金(LY20H140002);浙江省医药卫生科技计划(2020KY563)
第一作者:王诗莹(1994—),女,硕士研究生,主要从事口腔种植体周围组织状况相关研究;E-mail:wangshiying2006@126.com;https://orcid.org/0000-0001-9438-6095
通信作者:顾新华(1967—),男,博士,主任医师,博士生导师,主要从事人体硬组织仿生矿化和口腔种植临床研究;E-mail: guxh@zju.edu.cn;https://orcid.org/0000-0001-6674-1803

the three-dimensional space optimization, implant site enhancement by orthodontic extrusion and delayed orthodontic space opening.

[**Key words**] Orthodontics/therapies; Dental implantation; Dental restoration; Implant site; Soft and hard tissue augmentation; Review

[J Zhejiang Univ (Med Sci), 2020,49(1):124-130.]

长期牙列缺损导致的错殆畸形、骨缺损及软组织不足等问题,均会给种植修复带来一定挑战,种植前联合正畸治疗可以较好地解决此类问题[1]。术前正畸治疗可以使牙弓内间隙合理分配,为种植修复开辟足够的空间;此外,正畸运动可以正常刺激牙周韧带的生物学潜力,改变牙槽骨缺损的形态、增加软硬组织量,从而为种植手术及最终的美学修复创造有利的条件。

正畸治疗可增加从组织顶部到植入物平台间的组织深度,加强种植位点,有利于后期的种植修复[2];正畸治疗还有助于优化与相邻牙列相关的种植体角度,改善从种植体平台到相对的牙列间的弓间距离[3]。本文从种植位点的空间优化、软硬组织增量及种植修复时机选择等方面对种植前辅助正畸治疗进行了综述。

1 优化种植位点三维空间

长期的牙列缺损会导致邻牙移位及对殆牙伸长,从而引起咬合紊乱、食物嵌塞、殆龈距或近远中距不足等问题,这对口腔种植修复造成了一定困难。对于此类患者,种植前辅助正畸治疗可以改善缺牙区的三维修复空间,提高种植疗效。

1.1 垂直向空间优化

患者种植术前必须进行缺牙间隙殆龈距离的评估。牙冠高度空间指牙槽嵴顶平面到咬合面或切缘的距离,其理想高度为 8 ~ 12 mm,至少不小于 7 mm[4-5]。然而,临床上因长期缺牙且未进行修复而导致对殆牙过度伸长较为常见,缺牙部位殆龈距离不足,种植义齿修复困难。正畸微种植钉广泛应用于可预测的牙齿移动,避免选择长度小于 8 mm,直径小于 1.2 mm 的微种植钉,植入即刻或早期负荷 2 N 的力对微种植钉稳定性无影响[6]。正畸治疗中应用轻度持续正畸力加压以降低牙根吸收的风险,当牙压入一定幅度,为缺失牙提供足够的义齿修复间隙后即停止,可缩短疗程,也可降低牙根吸收风险。每月 0.784 ~ 0.980 N 的力可压低单颗磨牙 0.3 ~ 0.4 mm[7-9]。若仔细评估临床状况并及时调整创伤合,磨牙压低力并不会增加正畸引起的牙根吸收及其他明显的不良反应(如附着丧失)。使用局部正畸法压低伸长磨牙时,要认真评估种植体植入部位的解剖关系、明确种植体植入方向及合适的牵引力值,并避免伸长磨牙压低过程中对牙髓、牙根、牙周组织造成的不良影响[10]。

1.2 近远中向空间优化

长期缺牙可能会导致邻牙向缺牙区倾斜、扭转、漂移,从而造成缺牙间隙近远中修复空间不足,或修复体与邻牙间形成“黑三角”。牙列缺损伴邻牙倾斜者可用竖直弹簧、螺旋弹簧或方弓丝上弯制 T 形曲的方法,使邻牙直立并集中间隙再进行修复[11];倾斜牙直立过程中与对牙的咬合接触将不断发生变化,牙齿加力移动时,应加入使牙齿根向移位的“压低”力,在必要时还可进行适当地调殆,避免咬合创伤。多生牙拔除、先天缺牙或过小牙等情况会导致牙列存在散在间隙,通过正畸方法将间隙合理分配,再行种植治疗会达到较好的效果。患者经正畸联合种植序列治疗后咬合关系恢复正常且修复效果良好,其咬合力及分布与牙列正常者差异无统计学意义[12]。研究指出,正畸联合种植治疗在牙列缺损的临床研究中较单纯种植修复均取得了更好的治疗效果及更高患者满意度[13-16]。正畸治疗为种植修复术提供足够的冠部及种植体植入空间时,更要注意“控根”[17],应保持牙冠和根部整体移动,避免冠部移至合适位置后,根部向种植位点倾斜,导致种植体植入时伤及牙根,甚至骨整合失败。

1.3 唇(颊)舌向空间优化

对于牙列缺损伴错殆畸形的患者,咬合关系的考虑尤为重要。反殆、深覆殆和严重拥挤的患者局部牙槽骨高度较低。稳定的牙周状态、良好

的咬合关系对于种植修复是必不可少的,对远期的义齿维护亦会产生一定影响。适宜的覆殆覆盖是前牙种植美学需要考量的问题之一。当一个单一作用力施加于牙冠上,牙齿可围绕其阻抗中心旋转(如切牙的阻抗中心约在牙根中点的位置),此时牙槽顶和牙根尖处的压力增大。这种情况下,即使很小的力也可能使一半的牙周膜承受较大的压力[18]。基于比格犬的动物实验表明,倾斜和压低牙齿移动时,作用力能将牙龈损害转变为附着丧失相关性损害[19]。在倾斜移动时,施力应柔,并保持该范围内的清洁,以预防角形骨吸收的形成[18]。

2　引导软硬组织再生

正畸治疗通过空间重新分布,为种植修复术提供有利条件,但更值得关注的是正畸治疗能够重塑和再生骨组织和软组织。正畸引导再生技术可以进行三维骨重建,通过纠正骨质缺陷及恢复牙齿的正常膜龈关系,实现软硬组织增量,从而降低种植修复术的难度[20]。

2.1　引导骨组织再生

长期的牙齿缺失常导致缺牙区骨量不足、软组织凹陷等问题,不利于种植手术和后期美学修复。美学区域的薄弱皮质骨使其易于在牙周、根尖周感染和外部吸收后发生再吸收。牙槽骨骨量的维持及充足的软组织量对于前牙美学种植而言尤为重要[21]。种植手术操作时根据骨质情况可选择骨挤压技术[22]、骨劈开技术[23]、引导骨组织再生技术[24]、上颌窦提升[25]等方法行局部骨增量,骨量缺失较大时可于颏部或下颌外斜线取自体骨移植[26],甚至行二次引导性骨再生手术,以确保拥有足够的骨量及植入空间[21]。正畸引导骨组织再生通过正畸牵引为长期缺牙患者提供种植所需的骨量,既将创伤降到最低,又达到良好的治疗效果,不失为一种有效的种植骨增量方法。

2.1.1　引导垂直骨增量　牙周韧带是正畸牵引-成骨的关键装置[27]。牙周韧带纤维插入牙槽骨的骨膜中,当施加张力时,新的骨骼会沉积,因此,如果牵引力、牵引速度和炎症受到严格控制,牙周形态将会得到改善[20]。通过正畸牵引和挤压刺激牙周韧带的生物学潜能,增强、改变骨内缺损的形态,达到垂直骨增量的目的。种植前辅助正畸牵引的指征通常位于牙列的前牙区域,美学修复是主要关注点。文献中所选择的病例通常包括失去治疗价值的牙齿——由于严重的附着和骨质丧失、牙髓病变、根折、根管充填失败、根尖切除术失败或严重的根面龋[28]等问题需要拔除。种植前对这种牙齿进行正畸牵引可以促使唇侧骨和冠状骨的形成及软组织增强,从而避免了因种植位点骨增量需求而进行的创伤相对较大的外科手术。Korayem 等[29]总结了各种正畸牵引的治疗方案,建议对前牙和后牙分别施加 0.15 N 和 0.49 N 轻度且恒定的牵引力。正畸牵引以每月 1 ~ 2 mm 的速度进行,并且推荐每毫米牵引的稳定期为 1 个月[29-30]。当牙周受损时,通常需要将牙齿扭转[29,31]并倾向骨缺损较多方向,以增加该区域的牙槽骨体积[32]。牙齿牵引前需要事先进行根管治疗,以降低牙体敏感性或牙髓暴露可能[33]。正畸牵引过程中需要调整垂直牙冠高度,以消除咬合干涉及其与相对牙弓的接触[30]。在拔除受损牙齿后,应立即植入种植体或行额外的骨增量措施,以降低进一步骨吸收和软组织损失的风险[30]。

2.1.2　水平种植位点转换　长期缺牙的患者常伴有牙槽嵴的显著萎缩[34],特别是无牙槽嵴保存程序的患者。若存在牙周状况健康的邻近天然牙,正畸治疗可以作为一种手术替代方案,以达到缺牙区的牙槽骨增量。牙齿朝向邻近萎缩性牙槽嵴的正畸运动,使原本狭窄的牙槽嵴扩张,正畸治疗在增强邻近萎缩性牙槽骨中的应用被称为正畸种植位点切换(orthodontic implant site switching, OISS)[35]。该过程包括将相邻牙齿移入骨量缺损较多的缺牙区、关闭缺牙区域,并在其附近创建植入部位[36],这个新生成的“缺牙区”牙槽嵴通常具有足够的骨量,但主要是未成熟的束骨,且一旦形成就开始在高度和颊侧宽度上发生萎缩[37]。因此,种植术中建议使用引导性骨再生技术,补偿额外的预期骨质流失。术后需要固定保持器进行空间维护,直到完成种植体上部修复。OISS 可用于先天性牙齿发育不全的常见部位,如上、下颌侧切牙或前磨牙区。当正畸牙的牙根前表面与萎缩牙槽嵴的致密皮质骨结合时,常会发生侧根吸收[37]。通常在正畸结束后,牙根吸收终止。轻度正畸牵引力可减少压力区牙周膜的细胞坏死及侧根吸收,同时也能保证牙根的移动速率。临床上通过施力类型、大小及持续时间来控制治疗[38-40]。研究表明,受试者一侧牙齿被移动进入缺损区,可发

生附着丧失;将缺损区牙齿移出,并伴充分萌出时,骨缺损可减少或消除,从而增加骨改建[18]。

2.2 引导软组织再生

种植体周角化龈宽度至少为 2 mm[41],以保证最低的种植体周生物学宽度,形成种植体周的生物防线,有助于维持种植体边缘骨水平,防止唇侧骨板吸收[42]。缺乏足够角化龈的植体,其菌斑指数、平均牙龈指数、探诊出血及相应龈退缩增加,种植体周围炎发生率增高,影像学骨缺失更加明显[43-45]。对于长期缺牙的患者,由于缺少牙体组织的支撑,加之骨组织的吸收,牙齿周围的软组织呈现向内凹陷愈合的趋势。软组织不足是导致种植美学修复欠佳的主要原因之一,常见的软组织增量技术包括诱导软组织增量技术、结缔组织瓣移植技术、结合使用膜类材料等[42]。诱导软组织增量技术指运用软组织的自我生长能力来增加局部软组织量[42],分为自体诱导和修复体诱导两种,后者主要用于种植修复阶段牙龈轮廓塑形。自体诱导软组织增量具有创伤小、效果稳定等优点,但同时延长了种植手术的疗程。正畸牵引是获得垂直骨增量及龈乳头重建的可靠的非侵入性方法之一,Salama 等[46]运用正畸牵引法增加预种植区软组织量,利用牙周膜的再生潜力牵拉残根,增加局部骨组织的同时增加局部软组织量。正畸引导软组织增量,使种植手术中同期行二次引导性骨再生及引导性组织再生术成为可能,大大改善牙周病患者的修复效果[20]。

3 延迟正畸空间开放

上颌侧切牙先天发育不全在人群中的发生率为 1.5% ~3.6%[47-48],其治疗方案主要为正畸空间闭合和空间开放,前者关闭侧切牙间隙,通常需要在下颌弓中进行拔牙;后者开放理想修复空间,通过种植手术或固定义齿修复缺失牙。Jamilian 等[49]研究表明两者都能达到被广泛接受的审美效果,且对颞颌关节无明显损害。非专业人群的网络调查结果显示,空间关闭比空间开放更具有吸引力[47,50]。无论是空间开放还是空间闭合,治疗计划必须针对每位患者进行定制,可能涉及正畸、修复、种植、美学,不仅要达到最佳咬合,还要恢复自然平衡的微笑,以及具有长期稳定性。

拔牙后或先天性缺牙患者常出现牙槽嵴颊舌向和垂直骨量的减少[51-52]。临床试验及动物实验研究发现,这种骨缺损主要发生在颊侧[53-54],且牙槽嵴的宽度损失大于高度损失[55],这种主要位于颊侧的嵴部缺损通常需要进行骨移植或将植体更多地偏舌侧或腭侧植入。Uribe 等[56]通过模型测量发现,在正畸空间开放后,先天性缺失的上颌侧切牙牙槽嵴宽度和高度明显减少。而种植修复通常要求患者生长发育结束后才能进行,临床上要求患者年龄不小于 18 周岁。在生长发育期间,牙弓宽度变化很大。早期混合牙列过渡时期尖牙间宽度增加约 3 mm,上颌恒尖牙出现时再增加 2 mm,而下颌没有明显变化。6 ~ 16 岁时,磨牙间宽度逐渐增加,上颌为 4 ~5 mm,下颌为 2 ~ 3 mm[18]。正畸空间开放部位骨量的多少与开放时机的选择有关,延迟正畸空间开放在一定程度上可以减缓骨量流失。如侧切牙先天缺失患者可以在 13 岁后或接近骨骼生长结束时进行上颌尖牙的远端牵引,从而保留上颌侧切牙区域的颊腭侧骨量,为后期种植修复创造良好的条件[57]。对于缺牙患者而言,在短期内无法进行种植修复时,建议保留滞留乳牙或受损的牙齿,以降低拔牙后牙槽骨吸收的风险;对于先天缺牙且种植空间不足患者,应尽可能减少正畸空间开发与种植修复之间的间隔,以避免进一步牙槽骨吸收。

4 结 语

种植前辅助正畸治疗可以开辟足够的种植义齿间隙,从垂直向、水平向及颊舌的空间优化改善患者的咬合关系,提供种植修复所需的三维空间,为远期修复疗效夯实基础;通过正畸运动刺激牙周韧带的生物学潜力可以达到骨增量和软组织增量的目的,为植体-骨结合及红白修复美学提供必要条件,同时将手术创伤最小化;延迟正畸空间开放,选择适宜的时机启动正畸治疗,最大限度地维持种植位点的骨组织和软组织水平,极大地改善种植区的组织解剖结构,从而使种植手术能更顺利地进行,并为后期美学修复效果提供保障。

综上所述,种植前辅助正畸治疗不失为一种有效的多学科联合治疗手段。其中,严格选择适应证、个性化制订诊疗计划、序列治疗时机的选择及正畸、种植、修复各学科之间及时沟通和紧密衔接是良好结果的保障。

参考文献

[1] 王冠超,孙 强,马鹏华,等. 口腔正畸与种植义齿

联合治疗成人前牙错牙合畸形及牙列缺损的疗效观察[J]. **临床口腔医学杂志**,2019,35(12):748-751. DOI:10.3969/j.issn.1003-1634.2019.12.012.
WANG Guanchao, SUN Qiang, MA Penghua, et al. Efficacy of orthodontics combined with implant denture on adult anterior teeth malocclusion and dentition defect[J]. **Journal of Clinical Stomatology**,2019,35(12):748-751. DOI:10.3969/j.issn.1003-1634.2019.12.012. (in Chinese)

[2] WATANABE T, MARCHACK B W, TAKEI H H. Creating labial bone for immediate implant placement: a minimally invasive approach by using orthodontic therapy in the esthetic zone[J]. **J Prosthet Dent**, 2013,110(6):435-441. DOI:10.1016/j.prosdent.2013.09.003.

[3] MANTZIKOS T, SHAMUS I. Forced eruption and implant site development: an osteophysiologic response [J]. **Am J Orthod Dentofacial Orthop**,1999,115(5):583-591. DOI:10.1016/s0889-5406(99)70284-2.

[4] MISCH C E. **Contemporary implant dentistry**[M]. St. Louis: Mosby Publisher,2007:67-91.

[5] 林　野,邱立新,胡秀莲,等. **口腔种植学**[M]. 北京:北京大学医学出版社,2014:31-32.
LIN Ye, QIU Lixin, HU Xiulian, et al. **Oral Implatology**[M]. Beijing: Peking University Press, 2014:31-32. (in Chinese)

[6] CRISMANI A G, BERTL M H, CELAR A G, et al. Miniscrews in orthodontic treatment: review and analysis of published clinical trials[J]. **Am J Orthod Dentofacial Orthop**,2010,137(1):108-113. DOI:10.1016/j.ajodo.2008.01.027.

[7] AKAN S, KOCADERELI I, AKTAS A, et al. Effects of maxillary molar intrusion with zygomatic anchorage on the stomatognathic system in anterior open bite patients[J]. **Eur J Orthod**,2013,35(1):93-102. DOI:10.1093/ejo/cjr081.

[8] HERAVI F, BAYANI S, MADANI A S, et al. Intrusion of supra-erupted molars using miniscrews: clinical success and root resorption[J]. **Am J Orthod Dentofacial Orthop**, 2011, 139 (4 Suppl): S170-S175. DOI:10.1016/j.ajodo.2009.06.032.

[9] KAKU M, KOSEKI H, KAWAZOE A, et al. Treatment of a case of skeletal class II malocclusion with temporomandibular joint disorder using miniscrew anchorage[J]. **Cranio**,2011,29(2):155-163. DOI:10.1179/crn.2011.024.

[10] 包　扬,孙丽艳,刘　奕,等. 伸长磨牙的正畸-修复联合治疗[J]. **口腔医学**,2011,31(7):441-442.
BAO Yang, SUN Liyan, LIU Yi, et al. Orthodontic-prosthetic combined therapy for hyper-erupted molars [J]. **Stomatology**, 2011, 31 (7): 441-442. (in Chinese)

[11] 王　峰. 口腔正畸与修复的联合治疗[J]. **口腔颌面修复学杂志**,2014,15(2):128.
WANG Feng. Orthodontic treatment combined with prosthetic dentistry [J]. **Chinese Journal of Prosthodontics**,2014,15(2):128. (in Chinese)

[12] 张　维. 正畸联合种植序列在先天缺失牙治疗中的应用观察[J]. **现代医学**,2016,44(5):686-688.
ZHANG Wei. Application of orthodontic combined implant sequence in treatment of congenital missing teeth[J]. **China Journal of Modern Medicine**, 2016,44(5):686-688. (in Chinese)

[13] 李　石,段银钟,马兆峰,等. 正畸与种植联合治疗牙列缺损的临床研究[J]. **口腔医学**,2006,26(3):200-202. DOI:10.3969/j.issn.1003-9872.2006.03.015.
LI Shi, SONG Yinzhong, MA Zhaofeng, et al. Application of orthodontic-implant sequential treatment for restoration of dentition defects[J]. **Stomatology**, 2006,26(3):200-202. DOI:10.3969/j.issn.1003-9872.2006.03.015. (in Chinese)

[14] 喻爱霞,顾　超,徐霞娟. 单个牙缺失患者经正畸联合种植义齿治疗的临床效果研究[J]. **中国口腔种植学杂志**,2016,21(2):81-84.
YU Aixia, GU Chao, XU Xiajuan. Study on the clinical effect of single tooth loss patients treated with orthodontic combined implant[J]. **Chinese Journal of Oral Implantology**, 2016, 21 (2): 81-84. (in Chinese)

[15] 王志莉. 正畸治疗对种植义齿临床效果的影响[J]. **全科口腔医学杂志**, 2018, 5 (29): 11-12. DOI:10.3969/j.issn.2095-7882.2018.29.006.
WANG Zhili. Effect of orthodontic treatment on implant denture [J]. **General Journal of Stomatology**,2018,5(29):11-12. DOI:10.3969/j.issn.2095-7882.2018.29.006. (in Chinese)

[16] 徐建林. 正畸联合种植治疗先天性缺失牙患者的效果分析[J]. **全科口腔医学杂志**,2016,3(3):60-61.
XU Jianlin. The effect of orthodontics combined with implant in the treatment of congenital missing teeth [J]. **General Journal of Stomatology**, 2016, 3 (3):60-61. (in Chinese)

[17] 陈文雄,吴斯媛,史剑杰,等. 正畸种植联合治疗长期牙齿缺失[J/CD]. **中华口腔医学研究杂志(电子版)**,2014,8(1):55-58. DOI:10.3877/cma.j.issn.1674-1366.2014.01.013.
CHEN Wenxiong, WU Siyuan, SHI Jianjie, et al. An evaluation of the orthodontic-aided implant treatment in patients with teeth missing for a long period[J/CD]. **Chinese Journal of Stomatological Research(Electronic Edition)**,2014,8(1):55-58. DOI:10.3877/cma.j.issn.1674-1366.2014.01.

013. (in Chinese)

[18] LEE W, ROBERT L, KATHERINE W L, et al. **Orthodontics: current principles and techniques** [M]. 6th Edition. Singapore: Elsevier (Singapore) Pte Ltd, 2018.

[19] MARKS M H, CORN H. **Atlas of adult orthodontics: functional and esthetic enhancement** [M]. Philadelphia: Lea & Febiger, 1989.

[20] PAOLONE M G, KAITSAS R. Orthodontic-periodontal interactions: Orthodontic extrusion in interdisciplinary regenerative treatments [J]. **Int Orthod**, 2018, 16 (2): 217-245. DOI: 10.1016/j.ortho.2018.03.019.

[21] LAMBERT F, VINCENT K, VANHOUTTE V, et al. A methodological approach to assessing alveolar ridge preservation procedures in humans: hard tissue profile[J]. **J Clin Periodontol**, 2012, 39 (9): 887-894. DOI: 10.1111/j.1600-051X.2012.01900.x.

[22] YOUNES F, EGHBALI A, DE TROYER S, et al. Marginal and apical bone stability after staged sinus floor augmentation using bone condensing implants with variable-thread design: a two-dimensional analysis[J]. **Int J Oral Maxillofac Surg**, 2016, 45 (9): 1135-1141. DOI: 10.1016/j.ijom.2016.04.012.

[23] WAECHTER J, LEITE F R, NASCIMENTO G G, et al. The split crest technique and dental implants: a systematic review and meta-analysis[J]. **Int J Oral Maxillofac Surg**, 2017, 46 (1): 116-128. DOI: 10.1016/j.ijom.2016.08.017.

[24] ELGALI I, OMAR O, DAHLIN C, et al. Guided bone regeneration: materials and biological mechanisms revisited[J]. **Eur J Oral Sci**, 2017, 125 (5): 315-337. DOI: 10.1111/eos.12364.

[25] DANESH-SANI S A, LOOMER P M, WALLACE S S. A comprehensive clinical review of maxillary sinus floor elevation: anatomy, techniques, biomaterials and complications[J]. **Br J Oral Maxillofac Surg**, 2016, 54 (7): 724-730. DOI: 10.1016/j.bjoms.2016.05.008.

[26] NKENKE E, NEUKAM F W. Autogenous bone harvesting and grafting in advanced jaw resorption: morbidity, resorption and implant survival[J]. **Eur J Oral Implantol**, 2014, 7 Suppl 2: S203-S217.

[27] ALSAHHAF A, ATT W. Orthodontic extrusion for pre-implant site enhancement: Principles and clinical guidelines[J]. **J Prosthodont Res**, 2016, 60 (3): 145-155. DOI: 10.1016/j.jpor.2016.02.004.

[28] BRINDIS M A, BLOCK M S. Orthodontic tooth extrusion to enhance soft tissue implant esthetics[J]. **J Oral Maxillofac Surg**, 2009, 67 (11 Suppl): 49-59. DOI: 10.1016/j.joms.2009.07.013.

[29] KORAYEM M, FLORES-MIR C, NASSAR U, et al. Implant site development by orthodontic extrusion. A systematic review[J]. **Angle Orthod**, 2008, 78 (4): 752-760. DOI: 10.2319/0003-3219(2008)078[0752:ISDBOE]2.0.CO;2.

[30] HOCHMAN M N, CHU S J, TARNOW D P. Orthodontic extrusion for implant site development revisited: a new classification determined by anatomy and clinical outcomes[J]. **Semin Orthod**, 2014, 20 (3): 208-227. DOI: 10.1053/j.sodo.2014.06.007.

[31] ZUCCATI G, BOCCHIERI A. Implant site development by orthodontic extrusion of teeth with poor prognosis[J]. **J Clin Orthod**, 2003, 37 (6): 307-311; quiz 313.

[32] URIBE F, TAYLOR T, SHAFER D, et al. A novel approach for implant site development through root tipping[J]. **Am J Orthod Dentofacial Orthop**, 2010, 138 (5): 649-655. DOI: 10.1016/j.ajodo.2009.01.027.

[33] KIM S H, TRAMONTINA V A, PAPALEXIOU V, et al. Orthodontic extrusion and implant site development using an interocclusal appliance for a severe mucogingival deformity: a clinical report[J]. **J Prosthet Dent**, 2011, 105 (2): 72-77. DOI: 10.1016/S0022-3913(11)00012-6.

[34] HORVÁTH A, MARDAS N, MEZZOMO L A, et al. Alveolar ridge preservation. A systematic review[J]. **Clin Oral Investig**, 2013, 17 (2): 341-363. DOI: 10.1007/s00784-012-0758-5.

[35] ALI B F, HOMAYOUN H Z. **Vertical alveolar ridge augmentation in implant dentistry: a surgical manual**[M]. New Jersey: John Wiley & Sons, 2016: 30-37.

[36] KOKICH V G, KOKICH V O. Congenitally missing mandibular second premolars: clinical options[J]. **Am J Orthod Dentofacial Orthop**, 2006, 130 (4): 437-444. DOI: 10.1016/j.ajodo.2006.05.025.

[37] CHIU G, CHANG C, ROBERTS W E. Interdisciplinary treatment for a compensated Class II partially edentulous malocclusion: Orthodontic creation of a posterior implant site [J]. **Am J Orthod Dentofacial Orthop**, 2018, 153 (3): 422-435. DOI: 10.1016/j.ajodo.2016.11.029.

[38] REN Y, MALTHA J C, KUIJPERS-JAGTMAN A M. Optimum force magnitude for orthodontic tooth movement: a systematic literature review[J]. **Angle Orthod**, 2003, 73 (1): 86-92. DOI: 10.1043/0003-3219(2003)073<0086:OFMFOT>2.0.CO;2.

[39] DHOPATKAR A A, SLOAN A J, ROCK W P, et al. British orthodontic society, chapman prize winner 2003. A novel *in vitro* culture model to investigate the reaction of the dentine-pulp complex to orthodontic force[J]. **J Orthod**, 2005, 32 (2): 122-132. DOI:

10.1179/146531205225020979.

[40] PILON J J, KUIJPERS-JAGTMAN A M, MALTHA J C. Magnitude of orthodontic forces and rate of bodily tooth movement. An experimental study[J]. **Am J Orthod Dentofacial Orthop**, 1996, 110(1): 16-23. DOI: 10.1016/s0889-5406(96)70082-3.

[41] KAN J Y, RUNGCHARASSAENG K, LOZADA J L, et al. Facial gingival tissue stability following immediate placement and provisionalization of maxillary anterior single implants: a 2- to 8-year follow-up[J]. **Int J Oral Maxillofac Implants**, 2011, 26(1): 179-187.

[42] 温小娜,范亚伟,雷建华. 口腔种植的软组织增量技术研究进展[J]. **中国口腔种植学杂志**, 2017, 22(1): 42-46. DOI: 10.3969/j.issn.1007-3957.2017.01.013.
WEN Xiaona, FAN Yawei, LEI Jianhua. Progress of soft tissue incremental technology for oral implants [J]. **Chinese Journal of Oral Implantology**, 2017, 22(1): 42-46. DOI: 10.3969/j.issn.1007-3957.2017.01.013. (in Chinese)

[43] BOURI A J R, BISSADA N, AL-ZAHRANI M S, et al. Width of keratinized gingiva and the health status of the supporting tissues around dental implants[J]. **Int J Oral Maxillofac Implants**, 2008, 23(2): 323-326. DOI: 10.1016/j.ijom.2007.09.170.

[44] ZIGDON H, MACHTEI E E. The dimensions of keratinized mucosa around implants affect clinical and immunological parameters[J]. **Clin Oral Implants Res**, 2008, 19(4): 387-392. DOI: 10.1111/j.1600-0501.2007.01492.x.

[45] SCHROTT A R, JIMENEZ M, HWANG J W, et al. Five-year evaluation of the influence of keratinized mucosa on peri-implant soft-tissue health and stability around implants supporting full-arch mandibular fixed prostheses[J]. **Clin Oral Implants Res**, 2009, 20(10): 1170-1177. DOI: 10.1111/j.1600-0501.2009.01795.x.

[46] SALAMA H, SALAMA M. The role of orthodontic extrusive remodeling in the enhancement of soft and hard tissue profiles prior to implant placement: a systematic approach to the management of extraction site defects [J]. **Int J Periodontics Restorative Dent**, 1993, 13(4): 312-333.

[47] GILL D S. Space closing versus space opening for bilateral missing upper laterals-Aesthetic judgements of laypeople: A web-based survey[J]. **J Orthod**, 2016, 43(2): 93. DOI: 10.1080/14653125.2016.1190080.

[48] DALLEL I, MARWEN W, BEN ABDALLAH S, et al. Agenesis of the upper lateral incisors: Study of an orthodontic population and clinical illustration[J]. **Int Orthod**, 2018, 16(2): 384-407. DOI: 10.1016/j.ortho.2018.03.023.

[49] JAMILIAN A, PERILLO L, ROSA M. Missing upper incisors: a retrospective study of orthodontic space closure versus implant[J]. **Prog Orthod**, 2015, 16: 2. DOI: 10.1186/s40510-015-0072-2.

[50] QADRI S, PARKIN N A, BENSON P E. Space closing versus space opening for bilateral missing upper laterals-aesthetic judgments of laypeople: a web-based survey[J]. **J Orthod**, 2016, 43(2): 137-146. DOI: 10.1080/14653125.2016.1145880.

[51] SCHROPP L, WENZEL A, KOSTOPOULOS L, et al. Bone healing and soft tissue contour changes following single-tooth extraction: a clinical and radiographic 12-month prospective study[J]. **Int J Periodontics Restorative Dent**, 2003, 23(4): 313-323.

[52] VAN DER WEIJDEN F, DELL'ACQUA F, SLOT D E. Alveolar bone dimensional changes of post-extraction sockets in humans: a systematic review [J]. **J Clin Periodontol**, 2009, 36(12): 1048-1058. DOI: 10.1111/j.1600-051X.2009.01482.x.

[53] ARAUJO M G, LINDHE J. Dimensional ridge alterations following tooth extraction. An experimental study in the dog[J]. **J Clin Periodontol**, 2005, 32: 212-218. DOI: 10.1111/j.1600-051x.2005.00642.x.

[54] IASELLA J M, GREENWELL H, MILLER R L, et al. Ridge preservation with freeze-dried bone allograft and a collagen membrane compared to extraction alone for implant site development: a clinical and histologic study in humans [J]. **J Periodontol**, 2003, 74(7): 990-999. DOI: 10.1902/jop.2003.74.7.990.

[55] VAN DER WEIJDEN F, DELL'ACQUA F, SLOT D E. Alveolar bone dimensional changes of post-extraction sockets in humans: a systematic review [J]. **J Clin Periodontol**, 2009, 36(12): 1048-1058. DOI: 10.1111/j.1600-051X.2009.01482.x.

[56] URIBE F, CHAU V, PADALA S, et al. Alveolar ridge width and height changes after orthodontic space opening in patients congenitally missing maxillary lateral incisors[J]. **Eur J Orthod**, 2013, 35(1): 87-92. DOI: 10.1093/ejo/cjr072.

[57] BEYER A, TAUSCHE E, BOENING K, et al. Orthodontic space opening in patients with congenitally missing lateral incisors [J]. **Angle Orthod**, 2007, 77(3): 404-409. DOI: 10.2319/0003-3219(2007)077[0404:OSOIPW]2.0.CO;2.

[本文编辑 沈 敏 刘丽娜]