UNIWERSYTET MEDYCZNY
IM. PIASTÓW ŚLĄSKICH WE WROCŁAWIU

Sylwia Hnitecka

Ocena efektywności nowej metody rekonstrukcji kości żuchwy z wykorzystaniem indywidualizowanego 3D allogennego bloku kostnego w odcinkach uzębionych

Promotor: Prof. dr hab. n. med. Marzena Dominiak

Katedra i Zakład Chirurgii Stomatologicznej Uniwersytetu Medycznego we Wrocławiu

Promotor Pomocniczy: Dr hab. n. med. Cyprian Olchowy, prof. UJD

Collegium Medicum Uniwersytetu Jana Długosza w Częstochowie

Wrocław 2024

Podziękowania

Mojej Najbliższej Rodzinie- za pomoc, cierpliwość i ogromne wsparcie na każdym kroku

Moim Promotorom- Prof. dr hab. n. med. Marzenie Dominiak oraz dr hab.n. med. Cyprianowi Olchowemu, prof. UJD- za poświęcony czas i nieocenioną motywację do pracy naukowej

SPIS TREŚCI

1. WYKAZ SKRÓTÓW **5**
2. WYKAZ PUBLIKACJI STANOWIĄCYCH ROZPRAWĘ DOKTORSKĄ **6**
3. STRESZCZENIE **7**
4. ABSTRACT **11**
5. WPROWADZENIE **15**
6. CELE I ZAŁOŻENIA PRACY **18**
7. MATERIAŁY I METODY **19**
8. CYKL PUBLIKACJI STANOWIĄCYCH ROZPRAWĘ DOKTORSKĄ **21**
8.1. Publikacja 1: Analysis of alveolar ridge width in an area of central lower incisor using cone-beam computed tomography in vivo. 21
8.2. Publikacja 2: Advancements in alveolar bone reconstruction: A systematic review of bone block utilization in dental practice. 28
8.3. Publikacja 3: Possible Treatment of Severe Bone Dehiscences Based on 3D Bone Reconstruction- A Description of Treatment Methodology. 37
8.4. Publikacja 4: An innovative method for three-dimensional bone reconstruction of the anterior mandible with preserved dentition using an allogeneic bone block: A 6-month follow-up. 53
9. PODSUMOWANIE WYNIKÓW **66**
9.1. Publikacja 1: Analysis of alveolar ridge width in an area of central lower incisor using cone-beam computed tomography in vivo. 66
9.2. Publikacja 2: Advancements in alveolar bone reconstruction: A systematic review of bone block utilization in dental practice. 66
9.3. Publikacja 3: Possible Treatment of Severe Bone Dehiscences Based on 3D Bone Reconstruction—A Description of Treatment Methodology. 68
9.4. Publikacja 4: An innovative method for three-dimensional bone reconstruction of the anterior mandible with preserved dentition using an allogeneic bone block: A 6-month follow-up. 68
10. WNIOSKI **70**
11. PIŚMIENNICTWO **71**
12. SPIS RYCIN **73**
13. SPIS TABEL **74**
14. ZAŁĄCZNIKI **75**
14.1 Zgody Komisji Bioetycznej 75
14.2. Dorobek naukowy doktoranta 78
14.3. Oświadczenia współautorów 84

1. WYKAZ SKRÓTÓW

API	wierzchołek korzenia zęba- punkt referencyjny
CAD/CAM	ang. computer aided design/ computer aided manufacturing (projektowanie wspomagane komputerowo/ komputerowe wspomaganie wytwarzania)
CBCT	ang. cone beam computed tomography (tomografia wiązki stożkowej)
CEJ	ang. cementoenamel junction (granica szkliwno- cementowa)
FLOS	fizjoterapia- logopedia- osteopatia- stomatologia

2. WYKAZ PUBLIKACJI STANOWIĄCYCH ROZPRAWĘ DOKTORSKĄ

1. Dominiak M, **Hnitecka S**, Olchowy C, Olchowy A, Gedrange T. Analysis of alveolar ridge width in an area of central lower incisor using cone-beam computed tomography in vivo. *Ann Anat*. 2021;236:151699. doi:10.1016/j.aanat.2021.151699
   IF: 2,976
   Punkty: 100

2. **Hnitecka S**, Olchowy C, Olchowy A, Dąbrowski P, Dominiak M. Advancements in alveolar bone reconstruction: A systematic review of bone block utilization in dental practice [published online as ahead of print on May 23, 2024]. *Dent Med Probl.* doi:10.17219/dmp/181532
   IF: 2,7
   Punkty: 70

3. Dominiak M, **Hnitecka S**, Olchowy C, Dominiak S, Gedrange T. Possible Treatment of Severe Bone Dehiscences Based on 3D Bone Reconstruction—A Description of Treatment Methodology. *Applied Sciences*. 2021; 11(21):10299. doi.org/10.3390/app112110299
   IF: 2,838
   Punkty: 100

4. **Hnitecka S**, Dominiak M, Olchowy C, Gedrange T. An innovative method for three-dimensional bone reconstruction of the anterior mandible with preserved dentition using an allogeneic bone block: A 6-month follow-up. *Adv Clin Exp Med*. Published online August 9, 2024. doi:10.17219/acem/189840
   IF: 2,1
   Punkty: 70

Sumaryczny Impact Factor: 10,614
Sumaryczna liczba punktów: 340

3. STRESZCZENIE

Recesje są dowierzchołkowym przemieszczeniem brzegu dziąsłowego względem granicy szkliwno-cementowej. Dotyczą one dziąsła, więzadeł ozębnej, cementu korzeniowego oraz kości. Stanowią problem nie tylko estetyczny, ale także budzą obawę przed utratą zębów, dyskomfort, nadwrażliwość zębiny, próchnicę korzenia oraz mogą prowadzić do powstawania ubytków przyszyjkowych o niepróchnicowym pochodzeniu.

Etiologia recesji jest wieloczynnikowa. Można wyróżnić dwie główne grupy czynników: predysponujące oraz wywołujące. Czynniki predysponujące to rozwojowe zmiany morfologiczne, takie jak dehiscencje kostne, nieprawidłowa pozycja zęba, cienki biotyp dziąsła z niewystarczającą ilością dziąsła związanego oraz pull syndrome. Te zmiany mogą zwiększać ryzyko wystąpienia recesji. Z kolei czynniki wywołujące obejmują nawyki i stany, które przyczyniają się do powstawania recesji. Należą do nich m.in. czynniki traumatyzujące, takie jak nieprawidłowa technika szczotkowania, nawyki i parafunkcje, stan zapalny związany z akumulacją płytki nazębnej oraz różnego rodzaju interwencje stomatologiczne, w tym ortodontyczne ruchy zębów.

Problemem klinicznym jest współistnienie czynników predysponujących i wywołujących: przede wszystkim potrzeba leczenia ortodontycznego, co wymaga niewątpliwie opracowania algorytmów postępowania w takich przypadkach.

Wykazano, że indukowany ruch ortodontyczny zęba w kierunku obszaru bardzo cienkiej kości może powodować powstanie dehiscencji i w konsekwencji recesji. Idealnie zatem byłoby, gdyby korzeń pokryty był kością na wszystkich powierzchniach. Skłania to do poszukiwania rozwiązania dotyczących przywrócenia odpowiedniej ilości i morfologii kości, szczególnie przed planowanym leczeniem ortodontycznym.

Chirurgia regeneracyjna wyrostka zębodołowego obejmuje szereg technik zabiegowych z wykorzystaniem biomateriałów o różnych właściwościach. Szczególne wyzwanie stale stanowi rekonstrukcja kości w wymiarze pionowym. Dostępne doniesienia na temat znakomitych efektów rozległych rekonstrukcji obejmują głównie opisy przypadków regeneracji w odcinkach bezzębnych z wykorzystaniem bloków kostnych, gdzie ich dokładne dopasowanie i właściwa stabilizacja zapewniają uzyskanie pożądanego efektu. Blume i wsp. podkreślają zalety indywidualizowanych, allogennych bloków kostnych. Pozwala to na uniknięcie generowania kolejnego pola zabiegowego i związanego z nim potencjalnych komplikacji, a także umożliwia dokładne dopasowanie graftu do geometrii ubytku. W dostępnym piśmiennictwie brakuje jednak wystandaryzowanej i potwierdzonej metody

wielowymiarowej rekonstrukcji tkanki kostnej w odcinkach uzębionych, która przyniosłaby zadowalające efekty.

Niniejszą rozprawę doktorską stanowi cykl czterech publikacji. Sumaryczny IF= 10,614, sumaryczna liczba punktów= 340.

W pierwszej publikacji wykonano analizę problematyki występowania ubytków kostnych uzębionego przedniego odcinka części zębodołowej żuchwy. Badanie było oparte na radiologicznej ocenie w oparciu o skany tomografii stożkowej w grupie 100 losowo wybranych pacjentów. Mierzono szerokości kości w wybranych punktach referencyjnych w aspekcie zęba 31. Określono częstość występowania poszczególnych rodzajów ubytków kostnych oraz ich zaawansowanie. Na podstawie zgromadzonych danych stworzono własną graficzną modyfikację klasyfikacji ubytków kostnych Yang i wsp.

W drugiej publikacji dokonano przeglądu systematycznego piśmiennictwa, który miał na celu analizę charakterystyki, wad oraz zalet bloków kostnych wykorzystywanych w chirurgii regeneracyjnej wyrostka zębodołowego, wykonanych z różnych materiałów (autogennych, allogennych, ksenogennych). Scharakteryzowano również możliwości wykorzystania różnych metod ukierunkowanych na zwiększenie efektywności stopnia rekonstrukcji kości i usprawnienia zabiegu ze szczególnym opisem zalet indywidualizowania bloków allogennych.

Trzecia publikacja jest opisem przypadku, który przedstawia analizowaną metodę rekonstrukcji. Publikacja objaśnia etapy zabiegu oraz wykazuje jego efektywność w oparciu o porównawcze obrazy radiologiczne i kliniczne uzyskane przed zabiegiem oraz po upływie dwóch lat.

Zasadniczy projekt miał na celu ocenę radiologiczną efektywności analizowanej metody w grupie 32 pacjentów. W wystandaryzowany sposób dokonywano pomiarów w oparciu o badanie CBCT wykonane przed zabiegiem oraz po upływie pół roku. Mierzono szerokość kości w uprzednio określonych punktach referencyjnych względem dolnych zębów siecznych i kłów. Odnotowywano także ewentualną obecność dehiscencji i/lub fenestracji, zarówno po stronie przedsionkowej jak i językowej, oraz oceniano wówczas ich wymiar. Rodzaj i zaawansowanie ubytków kostnych klasyfikowano według dwóch przyjętych klasyfikacji.

W pierwszej publikacji dowiedziono, że problem występowania ubytków kostnych w zakresie przedniego odcinka uzębionej żuchwy jest bardzo częsty. W niniejszym badaniu wyniósł aż 91%, przy czym w 43% stwierdzono obecność jedynie bardzo cienkiej blaszki przedsionkowej, predysponującej do szybkiej resorpcji w obecności niekorzystnych czynników. Wykazano, że u znacznej część społeczeństwa najistotniejszym problemem są dehiscencje wargowe.

Przegląd systematyczny piśmiennictwa dotyczący charakterystyki bloków kostnych z różnych biomateriałów ukazał, że stale kość własna stanowi “złoty standard” w chirurgii regeneracyjnej wyrostka zębodołowego. Niemniej jednak, pod względem skuteczności, allogenne bloki kostne wykazują porównywalną skuteczność do bloków autogennych, charakteryzując się ponadto niskim współczynnikiem resorpcji. Co ważne, stwierdzono, że względy bezpieczeństwa faworyzują alloprzeszczepy, ponieważ ich zastosowanie eliminuje niekiedy stosunkowo wysokie ryzyko powikłań w miejscu dawczym. Opisując nowoczesne metody zwiększające efektywność zabiegów rekonstrukcyjnych z wykorzystaniem bloków kostnych, zwrócono uwagę na możliwość indywidualizowania bloków allogennych, która ma szczególne znaczenie, zapewniając idealne położenie i wymiary bloku. Procedura chirurgiczna z indywidualizowanymi blokami allogennymi jest znacznie prostsza i szybsza, gdyż nie wymaga modelowania i dopasowywania graftu.

Publikacja oparta na opisie przypadku analizowanej metody rekonstrukcji kości wykazała istotną przydatność CBCT w aspekcie projektowania wspomaganego komputerowo i następczego wytwarzania projektu. Technologia ta umożliwia uzyskanie indywidualizowanego, idealnie dopasowanego do miejsca biorczego bloku kostnego. Odnotowano zadowalający efekt zabiegu, ponieważ w kontrolnym badaniu radiologicznym po 2 latach zauważono znaczny poziom odbudowy kości, wynoszący aż 6,5 mm w wymiarze pionowym. Ponadto stwierdzono obecność nowo wytworzonej warstwy kości zbitej. Tym samym wstępnie dowiedziono skuteczności tej nowatorskiej metody.

Podstawowa analiza skuteczności rekonstrukcji wykazała istotne statystycznie różnice w wymiarach kości w większości przypadków, porównując obrazy radiologiczne przed zabiegiem i po 6 miesiącach. Uśrednione wartości średnich dla każdego zęba analizowanego na określonych wysokościach referencyjnych wynosiły: CEJ-2: 2,9 mm, ½ CEJ-2: 2,7 mm, ¼ CEJ-2: 1,9 mm, API: 1,4 mm. Maksymalny pionowy wzrost kości zaobserwowano przy zębie 43 (9,9 mm), następnie 32 (9,8 mm), 33 (8,5 mm), 31 (8,4 mm), 42 (8 mm), 41 (7 mm). Nie stwierdzono istotnego wpływu wieku i płci na końcowy efekt zabiegu. U znacznego odsetka pacjentów początkowo występowały niekorzystne czynniki, które mogą negatywnie wpływać na skuteczność odbudowy kości – cienki biotyp dziąsła i recesje, nadmierna aktywność mięśnia bródkowego. Nie było jednak istotnej statystycznie różnicy pomiędzy tymi pacjentami a pacjentami bez powyższych czynników. Wynik ten wskazuje na konieczność odpowiedniego przygotowania pacjenta zgodnie z zastosowanym algorytmem. Idealny efekt terapeutyczny uzyskano u 24 (75%) pacjentów, a u pozostałych efekt był zadowalający.

Na podstawie tych badań wyciągnięto następujące główne wnioski:

1) Problem częstości występowania ubytków kostnych w przednim odcinku uzębionej żuchwy, występujący u znacznej części społeczeństwa, wymaga opracowania określonych algorytmów diagnostycznych i terapeutycznych, szczególnie u pacjentów przed i w trakcie leczenia ortodontycznego,

2) Rekonstrukcja kości z użyciem allogennego, indywidualizowanego bloku kości gąbczastej w technologii 3D optymalizuje zabieg pod kątem technicznym oraz pozwala na osiągnięcie zadowalającego efektu, w tym wytworzenie nowej warstwy kości zbitej, co świadczy o znakomitej adaptacji funkcjonalnej przeszczepu,

3) Opisana i analizowana metoda jest jedyną przewidywalną i skuteczną w aspekcie trójwymiarowej- w tym wertykalnej regeneracji kości w odcinkach z obecnym uzębieniem.

4. ABSTRACT

Recessions are characterized by the apical displacement of the gingival margin in relation to the cementoenamel junction. They affect the gingiva, periodontal ligaments, root cementum, and bone. This condition is not solely an aesthetic issue; it also raises concerns about tooth loss, discomfort, dentin hypersensitivity, root caries, and may cause the formation of cervical lesions of non-carious origin.

The etiology of recessions is multifactorial. It involves both predisposing and causative factors. Predisposing factors include developmental morphological changes such as bone dehiscence, incorrect tooth position, thin biotype with insufficient attached gingiva, or pull syndrome, all of which may increase the risk of recession. Causative factors, in turn, include habits and conditions that contribute to the development of recessions. These include traumatic factors such as improper tooth brushing techniques, habits and parafunctions, inflammation associated with plaque accumulation, and various dental interventions, including orthodontic tooth movements.

The clinical problem involves the coexistence of predisposing and causative factors, particularly the need for orthodontic treatment, which necessitates the development of specific management algorithms. It has been shown that induced orthodontic tooth movement towards an area of very thin bone can cause dehiscence and, consequently, recession. Ideally, the root should be covered with bone on all surfaces. This leads us to seek solutions to restore the appropriate amount and morphology of bone, especially before planned orthodontic treatments.

Regenerative alveolar surgery encompasses a range of surgical techniques utilizing biomaterials with various properties. Vertical bone reconstruction remains a particular challenge. The available reports on the excellent results of extensive reconstructions primarily consist of case descriptions involving regeneration in edentulous areas, often presented in scenarios where bone blocks are used. The precise adaptation and adequate stabilization of these bone blocks ensure the desired outcomes. Blume et al. emphasize the advantages of individualized, allogeneic bone blocks, which allow for the avoidance of creating an additional surgical site and the associated potential complications, as well as the precise adaptation of the graft to the defect's geometry. However, the current literature lacks a standardized and validated method for the multidimensional reconstruction of bone in areas with preserved dentition that would consistently provide satisfactory results.

The dissertation consists of a series of four publications with a total Impact Factor (IF) of 10,614 and total points amounting to 340.

The first publication analyzed the prevalence of bone defects in the anterior area of the mandible with preserved dentition. This study was based on a radiological assessment using cone beam computed tomography (CBCT) scans in a group of 100 randomly selected patients. Bone widths were measured at selected reference points in relation to tooth 31. The frequency and advancement of various types of bone defects were determined. Based on the collected data, a graphical modification of Yang et al.'s classification of bone defects was created.

The second publication includes a systematic review of the literature aimed at analyzing the properties, disadvantages, and advantages of bone blocks used in regenerative alveolar surgery, which are made from various materials (autogenous, allogeneic, xenogeneic). The review also characterizes various methods aimed at increasing the effectiveness of bone reconstruction and improving procedural outcomes, with particular emphasis on the advantages of individualizing allogeneic blocks.

The third publication is a case report that presents the analyzed reconstruction method. This publication explains the stages of the procedure and demonstrates its effectiveness based on comparative radiological and clinical images obtained before the procedure and two years after.

The main project aimed at the radiological evaluation of the effectiveness of the analyzed method in a group of 32 patients. The measurements were standardized using CBCT examinations performed before the procedure and six months afterwards. Bone width was measured at predetermined reference points relative to the lower incisors and canines. The possible presence of dehiscences and/or fenestrations, on both the vestibular and lingual sides, was also recorded and their sizes assessed. The type and advancement of the bone defects were classified according to two recognized classifications.

The first publication demonstrated that bone defects in the anterior part of the dentate mandible are very common. In this study, the prevalence was as high as 91%, with 43% having only a very thin vestibular plate, which predisposes to rapid resorption in the presence of unfavorable factors. It was found that the most significant problem in a substantial portion of the population is labial dehiscence.

A systematic review of the literature on the properties of bone blocks made from different biomaterials revealed that autogenous bone is the "gold standard" in regenerative surgery of the alveolar process. However, in terms of efficacy, allogeneic bone blocks are comparable to autogenous blocks and also have a low resorption rate. It is important to note that safety considerations favor allogeneic bone blocks, as their use sometimes eliminates the very high risk of complications at the donor site. When describing modern methods that increase the effectiveness of reconstructive procedures using bone blocks, the possibility of individualizing allogeneic blocks was highlighted. This is of particular importance as it ensures the ideal position and size of the block. The surgical procedure with individualized allogeneic blocks is much easier and faster because it does not require the modeling and adjustment of the graft. The publication, based on a case report of the analyzed bone reconstruction method, demonstrated the significant benefits of CBCT in terms of computer-aided design and subsequent fabrication of the design. This technology makes it possible to obtain an individualized bone block that is perfectly matched to the recipient site. The outcome of the procedure was satisfactory, as a radiologic follow-up after 2 years showed a significant level of bone reconstruction, with vertical growth measuring up to 6.5 mm. The presence of a newly formed layer of cortical bone was also noted, which initially proved the effectiveness of this innovative method.

The basic analysis of the effectiveness of the reconstruction showed statistically significant differences in bone dimensions in most cases when comparing the radiologic images before the procedure and 6 months thereafter. The average mean values for each tooth analyzed at specific reference heights were: CEJ-2: 2.9 mm, ½ CEJ-2: 2.7 mm, ¼ CEJ-2: 1.9 mm, API: 1.4 mm. The maximum vertical bone growth was observed at tooth 43 (9.9 mm), followed by 32 (9.8 mm), 33 (8.5 mm), 31 (8.4 mm), 42 (8 mm), and 41 (7 mm). There was no significant influence of age or gender on the final outcome of the procedure. A significant percentage of patients exhibited initial unfavorable factors that could negatively affect the efficacy of bone reconstruction, such as a thin gingival biotype and recession, as well as excessive activity of the mentalis muscle. However, no statistically significant difference was found between these patients and those without the aforementioned factors, indicating the need to properly prepare the patient according to the applied algorithm. An ideal therapeutic effect was achieved in 24 (75%) patients, while the effect was satisfactory in the remaining patients.

Based on this research, the following main conclusions were drawn:

1) The high frequency of bone defects in the anterior part of the mandible with preserved dentition, which affects a significant proportion of the population, necessitates the development of specific diagnostic and therapeutic algorithms, particularly for patients before and during orthodontic treatment,

2) Bone reconstruction using an allogenic individualized 3D cancellous bone block optimizes the procedure from a technical standpoint and allows for satisfactory outcomes. This includes the formation of a new layer of cortical bone, demonstrating the excellent functional adaptation of the graft,
3) The method described and analyzed is the only predictable and effective approach for three-dimensional—including vertical—bone regeneration in areas with existing teeth.

5. WPROWADZENIE

Recesje polegają na dowierzchołkowym przemieszczeniu brzegu dziąsłowego względem granicy szkliwno- cementowej (CEJ- cementoenamel junction). Mogą występować pojedynczo, być uogólnione lub obejmować jedną albo większą ilości powierzchni zęba. Problem ten jednak nie dotyczy tylko dziąsła. Stwierdzono bowiem, że wiąże się on również z utratą więzadeł ozębnej, cementu korzeniowego oraz, co bardzo ważne, kości. W związku z powyższym rekomenduje się używania terminu “recesje przyzębia” zamiast powszechnie używanego “recesje dziąseł” [1].

Taki stan często stwarza problem estetyczny, zwłaszcza w odcinku przednim. Skutkuje także obawą przed utratą zębów w przypadku progresji i często powoduje dyskomfort, nadwrażliwość zębiny, próchnicę korzenia wskutek zwiększonego gromadzenia się płytki nazębnej oraz ubytki przyszyjkowe niepróchnicowego pochodzenia, spowodowane narażeniem powierzchni korzenia na działanie środowiska jamy ustnej [2].

Etiologia recesji jest wieloczynnikowa. Zasadniczo wyróżnia się dwie grupy czynników: predysponujące oraz wywołujące. Czynnikami predysponującymi są głównie rozwojowe zmiany morfologiczne, które mogą zwiększać ryzyko wystąpienia recesji, natomiast czynnikami wywołującymi są nawyki lub stany, które przyczyniają się do ich powstania. Do uwarunkowań morfologicznych zalicza się przede wszystkim dehiscencje kostne, nieprawidłową pozycję zęba, cienki biotyp z niewystarczającą ilością dziąsła związanego oraz pull syndrome spowodowany nieprawidłowym przyczepem wędzidełek. W drugiej grupie czynników znajdują się m. in. czynniki traumatyzujące, takie jak nieprawidłowa technika szczotkowania, nawyki i parafunkcje, stan zapalny związany z akumulacją płytki nazębnej oraz, co istotne, leczenie stomatologiczne, czy też jatrogenia stomatologiczna, włączając ortodontyczne ruchy zębów [3].

Pojawia się zatem ważne klinicznie zagadnienie dotyczące sytuacji, w której istnieją pierwotnie czynniki predysponujące i jednocześnie niemożliwe do uniknięcia czy wyeliminowania czynniki wywołujące- przede wszystkim potrzeba leczenia ortodontycznego. Czy wobec tego w sytuacji cienkiego biotypu dziąsła, bardzo cienkiej warstwy kości pokrywającej korzeń czy dehiscencji należy bezwzględnie unikać leczenia ortodontycznego?

Czy u pacjentów z zaawansowanymi recesjami przyzębia ze znaczną utratą kości należy spodziewać się niepowodzenia dotychczas znanych technik pokrywania recesji z wykorzystaniem przeszczepów wolnych oraz płatów przesuniętych, gdzie powszechnie wiadomo o malejącej skuteczności takich zabiegów wraz ze wzrostem zaawansowania problemu [4,5]?

Niewątpliwie podjęcie tego zagadnienia wymaga ustalenia częstości występowania tego typu sytuacji w populacji. W przypadku potwierdzenia wagi tego klinicznego problemu racjonalne byłoby opracowanie i ustalenie optymalnego postępowania w takich sytuacjach.

Zagadnienie dotyczące występowania recesji przyzębia w kontekście leczenia ortodontycznego jest przedmiotem badań od wielu lat. Wykazano, że indukowany ruch ortodontyczny zęba w kierunku obszaru bardzo cienkiej kości może prowadzić do powstania dehiscencji, a w konsekwencji recesji. Pierwotnie występujące ubytki kostne w zakresie wyrostka zębodołowego (wcześniej wspomniane dehiscencje i fenestracje) stanowią zatem istotny czynnik predysponujący recesji. Podkreślane jest, że ideałem byłoby, gdyby zęby pozostawały „otoczone" tkanką kostną na wszystkich swoich powierzchniach. Ruch ortodontyczny powinien być zatem dokładnie zaplanowany, aby nie przekraczać granic kostnych [6].

Rozwiązaniem obiecującym może okazać się wówczas próba przywrócenia adekwatnej ilości i morfologii kości pokrywającej korzenie zębów, szczególnie przed planowanym leczeniem ortodontycznym. W związku z tym byłoby to eliminowanie czynników predysponujących w obliczu spodziewanego wystąpienia istotnego czynnika wywołującego.

Szeroko pojęte zabiegi rekonstrukcyjne kości szczęk obejmują wiele technik z wykorzystaniem różnych biomateriałów o specyficznych właściwościach i różnym potencjale regeneracyjnym. Bez względu na wybór materiału, kluczowe jest zawsze utrzymanie adekwatnej stabilności przeszczepu [7]. Stosunkowo przewidywalną i technicznie łatwą procedurą są augmentacje ubytków śródściennych, gdzie ściany ubytku kostnego stanowią naturalną trójwymiarową podporę dla biomateriału [8,9]. Bardziej wymagające i tym samym mniej przewidywalne są zabiegi rekonstrukcji kości w wymiarze poziomym i szczególnie w pionowym [10].

Istnieje jednak wiele doniesień na temat skutecznych i wielokrotnie spektakularnych efektów rozległych rekonstrukcji kostnych, przede wszystkim w kontekście implantologicznym w odcinkach bezzębnych. Zadowalające rezultaty przedstawiane są głównie w przypadkach wykorzystania bloków kostnych, gdzie ich dokładne dopasowanie i właściwa stabilizacja zapewniają uzyskanie pożądanego efektu. Blume i wsp. podkreślają zalety zindywidualizowanych, allogennych bloków kostnych nie tylko z powodu możliwości uniknięcia generowania kolejnego pola zabiegowego i związanego z nim potencjalnych komplikacji jak w przypadku kości autogennej, ale przede wszystkim możliwości dokładnego dopasowania graftu do geometrii ubytku. Należy mieć na uwadze fakt, że raportowane powikłania wiążą się niemal wyłącznie z kontaminacją, która może wystąpić albo podczas wielokrotnego dostosowywania bloków do morfologii ubytku, albo na skutek nieprawidłowego zarządzania tkankami miękkimi, skutkującego ich perforacją i obnażeniem przeszczepu [11,12].

Dostępne w piśmiennictwie obserwacje opierają się jednak na rekonstrukcjach kości w bezzębnych odcinkach. Jedyny opis przypadku próby rekonstrukcji przy zębach został opisany przez Rasperini i wsp. w 2015 roku. Autorzy wykorzystali trójwymiarowy bioresorbowalny szkielet z czynnikami wzrostu. Zaobserwowali 3- milimetrową poprawę w zakresie przyczepu łącznotkankowego oraz częściowe pokrycie obnażonego korzenia. Finalnie jednak, po 14 miesiącach, stwierdzono, iż pozostało 75,9% masy cząsteczkowej rusztowania, a gojenie dotyczyło głównie tkanki łącznej, z minimalnymi oznakami regeneracji kości [13].

Brakuje zatem wystandaryzowanej i potwierdzonej metody wielowymiarowej rekonstrukcji tkanki kostnej w odcinkach uzębionych.

6. CELE I ZAŁOŻENIA PRACY

Nadrzędnym celem niniejszej pracy doktorskiej było ustalenie wskazań do nowatorskiej metody rekonstrukcji kości żuchwy z wykorzystaniem trójwymiarowego, indywidualizowanego allogennego bloku kostnego, a przede wszystkim ocena jej efektywności poprzez dokonanie analizy radiologicznej.

Pośrednio cel realizowano poprzez:

1. Ustalenie problematyki oraz częstości występowania fenestracji oraz dehiscencji kostnych w zakresie przedniego odcinka żuchwy w grupie losowo wybranych pacjentów.
2. Przedstawienie nowej metody rekonstrukcji kości żuchwy z użyciem 3D bloku z kości allogennej w dwuletniej obserwacji.
3. Analizę wad i zalet bloków kostnych z różnych materiałów w kontekście ich wykorzystania w procedurach rekonstrukcji kości szczęki i żuchwy.

Wymienione cele badawcze zrealizowano w cyklu publikacji składającym się z dwóch projektów badawczych bazujących na ocenie radiologicznej, jednego opisu przypadku z przedstawieniem analizowanej metody oraz jednego przeglądu systematycznego.

7. MATERIAŁY I METODY

Koncepcja powstania oraz uwzględnienia publikacji numer 1 w niniejszej dysertacji oparta jest na chęci stworzenia swoistego “wstępu” do cyklu prac oraz przedstawienia problematyki ubytków kostnych w odcinkach uzębionych, co podkreśla celowość rozwijania tego zagadnienia.

Wstępnie dokonano analizy problematyki występowania defektów kostnych uzębionego przedniego odcinka części zębodołowej żuchwy. W tym celu przeprowadzono radiologiczną ocenę tego rejonu anatomicznego w oparciu o badanie tomografii stożkowej (CBCT- cone beam computed tomography) w grupie 100 losowo wybranych pacjentów jednego z gabinetów stomatologicznych. Dokonywano pomiarów szerokości kości w określonych uprzednio punktach referencyjnych w odniesieniu do zęba 31. Określono ponadto częstość występowania poszczególnych rodzajów ubytków kostnych oraz ich zaawansowanie, z wyodrębnieniem sytuacji, w których korzeń jest pokryty bardzo cienką blaszką zbitą (<1 mm), predysponującą do szybkiej resorpcji w niekorzystnych warunkach, w tym w czasie leczenia ortodontycznego. Zgromadzone dane poddano analizie statystycznej, a także stworzono własną graficzną modyfikację klasyfikacji ubytków kostnych Yang i wsp. jako jedynej dotychczas opracowanej takiej klasyfikacji [14].

Kolejno podjęto analizę charakterystyki, wad oraz zalet bloków kostnych wykorzystywanych w chirurgii regeneracyjnej wyrostka zębodołowego, wykonanych z różnych materiałów (autogennych, allogennych, ksenogennych). Dokonano przeglądu systematycznego z definicją kryteriów w formacie PICOS: P (populacja)- ogólnie zdrowi dorośli > 18 roku życia z defektami kości szczęki/ żuchwy, uniemożliwiającymi leczenie implantoprotetyczne; I (interwencja oceniana)- augmentacja/ rekonstrukcja kości z użyciem bloków kostnych; C (komparatory)- różne rodzaje bloków kostnych; O (wyniki)- efektywność regeneracji, bezpieczeństwo oraz porównanie charakterystyki poszczególnych rodzajów bloków; S (metodyka)- badania porównawcze oraz kohortowe. Wyodrębniono także informacje na temat dodatkowo wdrażanych metod, ukierunkowanych na zwiększenie efektywności stopnia rekonstrukcji kości oraz usprawnienia zabiegu, ze szczególnym zwróceniem uwagi na możliwość indywidualizacji bloków allogennych.

Analizowaną metodę rekonstrukcji kości opisano i przedstawiono na przypadku jednego z pacjentów, który został do niej zakwalifikowany z uwagi na recesje przyzębia i patologiczną ruchomość zębów w odcinku przednim żuchwy. Objaśniono poszczególne etapy zabiegu, a jego efektywność przedstawiono w oparciu o porównawcze obrazy radiologiczne i kliniczne uzyskane przed zabiegiem oraz po upływie dwóch lat.

Zasadniczym projektem badawczym była radiologiczna ocena efektywności opisanej metody rekonstrukcji kości w półrocznej obserwacji. Analiza uwzględniała skany CBCT 32 dorosłych pacjentów (25 kobiet i 7 mężczyzn), u których przeprowadzono rekonstrukcję części zębodołowej żuchwy w uzębionym odcinku przednim z wykorzystaniem indywidualizowanego allogennego bloku 3D zgodnie z wyżej opisanym schematem. Kwalifikacja do zabiegu poprzedzona była wykonaniem diagnostyki radiologicznej i dokumentacji fotograficznej oraz pozyskaniem pisemnej zgody pacjentów. Opisano poszczególne etapy przygotowawcze do właściwego zabiegu augmentacyjnego z uwzględnieniem techniki FLOS i chirurgii śluzówkowo- dziąsłowej. Procedura chirurgiczna została wykonana w ten sam uprzednio opisany sposób, przez tego samego operatora (M.D). Po upływie pół roku pacjentom wykonano kontrolne badania CBCT przy użyciu tego samego sprzętu radiologicznego. Dokonano jednakowych pomiarów na skanach wykonanych przed zabiegiem i kontrolnych, zgodnie ze schematem zastosowanym w badaniu oceniającym częstość występowania ubytków kostnych. Mierzono szerokość kości w następujących punktach referencyjnych względem dolnych zębów siecznych i kłów (33, 32, 31, 41, 42, 43; łącznie 192 zęby) w płaszczyźnie strzałkowej: CEJ- 2mm (fizjologiczny poziom kości brzeżnej), na wysokości wierzchołka korzenia, w połowie oraz w 1/4 odległości od CEJ- 2 mm do wierzchołka. W płaszczyźnie osiowej dokonywano pomiaru kości w wymiarze przedsionkowo- językowym mezjalnie i dystalnie względem danego zęba. Odnotowywano ewentualną obecność dehiscencji i/lub fenestracji kostnych, zarówno po stronie przedsionkowej, jak i językowej, oraz oceniano wówczas ich wymiar. Rodzaj i zaawansowanie ubytków kostnych klasyfikowano według Yang i wsp. [13] oraz według własnej modyfikacji tej klasyfikacji.

Do publikacji artykułów o danej tematyce uzyskano dwie zgody Komisji Bioetycznej: KB-530/2021 oraz KB 284/2023N.

Przedstawiona i analizowa metoda rekonstrukcji kości uzyskała patent: T. Gedrange, M. Dominiak, “Verwendung einer Kenngröße eines Individuums zur Beurteilung des Risikos eines Zahnfleisch- und/oder Knochenschwundes an einem Schneidezahn”, European Patent Office, Munich, Germany, 2016, EP3287097B1.

8. CYKL PUBLIKACJI STANOWIĄCYCH ROZPRAWĘ DOKTORSKĄ

8.1. Publikacja 1: Analysis of alveolar ridge width in an area of central lower incisor using cone-beam computed tomography in vivo.

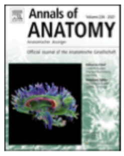
Annals of Anatomy 236 (2021) 151699

ELSEVIER

Contents lists available at ScienceDirect

Annals of Anatomy

journal homepage: www.elsevier.com/locate/aanat



RESEARCH ARTICLE

Analysis of alveolar ridge width in an area of central lower incisor using cone-beam computed tomography in vivo☆

Marzena Dominiak[a], Sylwia Hnitecka[b], Cyprian Olchowy[a,*], Anna Olchowy[c], Tomasz Gedrange[a,d]

[a] *Department of Oral Surgery, Wroclaw Medical University, Wroclaw, Poland*
[b] *Department of Maxillofacial Surgery, Wroclaw Medical University, Wroclaw, Poland*
[c] *Department of Experimental Dentistry, Wroclaw Medical University, Wroclaw, Poland*
[d] *Department of Orthodontics, Dresden Medical University, Dresden, Germany*

A R T I C L E I N F O

Article history:
Received 30 September 2020
Received in revised form
28 December 2020
Accepted 10 January 2021
Available online 8 February 2021

Keywords:
Bone resorption
Fenestration
Dehiscence
Orthodontic treatment
Gingivo-dentoalveolar complex
Alveolar process
Classification

A B S T R A C T

Background: Planning a comprehensive dental treatment should include assessment and classification of the condition of the alveolar ridge. Existing classifications are insufficient. This study aimed to investigate the frequency of bone deficiencies in the anterior mandible and to develop an extension of one of the alveolar bone dehiscence classification.
Methods: Cone-beam computed tomography scans of 100 adults with the mean age of 36.75 ± 11.77 years were analyzed. Measurements were taken from the 31. tooth.
Results: The presence of any bone defect was found in 91 (91%) of cases. Fenestrations were detected in 9% of study images, and dehiscence were detected in 90% of study images. A thin alveolar plate of below 0.2 mm independent from the side was found in 37 (37%) of cases. The mean height of buccal fenestration was 3.10 ± 1.09 mm, and the mean height of lingual fenestration was 2.73 ± 0.91 mm. The mean height of buccal dehiscence was 4.39 ± 1.82 mm, and the mean height of lingual dehiscence was 4.27 ± 2.49 mm.
Conclusions: An attempt to restore the correct morphology of the alveolar process after improper treatment constitutes a therapeutic challenge. The frequent occurrence of bone deficiency prompts establishing safe treatment planning strategies, including careful assessment of the alveolar process supported by the comprehensive classification of bone defects.

1. Introduction

Planning a comprehensive dental treatment should include minimizing the occurrence of side effects, especially taking into account orthodontic, implantological, or periodontological treatment. Ignoring the exact morphological conditions within the treated region may result in even worsening of the existing pathology (Dominiak, 2010). The anterior mandible creates a particular therapeutic challenge. Taking into account the close interdependence between soft tissues and underlying bone, the potential causes of periodontal recession should be considered. One of the most popular classifications of marginal tissue recession was developed in 1985 by Miller. It is a morphological classification based on the relation of the level of soft tissue recession to the bone level in interdental spaces. He described recession on teeth without malposition in I and II class, and secondary malposition in III or IV class (Miller, 1985). In 2009, Dominiak proposed a modification based on the additional description of I and II Miller's class as Ia and IIa in case of primary malposition teeth. It was important due to the directions of perio-ortho treatment and analysis of the causes of the recession (Dominiak and Gedrange, 2014).

Primary- and secondary-acquired causes of recession have been well studied. Among the primary causes, the most frequently mentioned are anatomical and morphological conditions of the gingivo-dentoalveolar complex. The risk of developing periodontal recession increases in patients with narrow and high mandibular symphysis, which is related to mandibular posteriorotation, as the symphysis is the center of its anterior growth (Handelman, 1996). Higher bone density also increases the risk of developing a recession (Wehrbein et al., 1996). Despite that the incorrect position of the lower incisors such as crowding, rotations, or extrapositions contribute to a recession, even in cases with correctly placed

☆ This paper belongs to the special issue Dentistry 2017.
* Corresponding author at: Cyprian Olchowy, Department of Oral Surgery, Wrocław Medical University, 50-425 Wrocław, Poland.
E-mail address: cyprian.olchowy@umed.wroc.pl (C. Olchowy).

https://doi.org/10.1016/j.aanat.2021.151699
0940-9602/© 2021 Published by Elsevier GmbH.

teeth, roots can be covered only with a very thin layer of cortical bone, which tends to resorption (Newman et al., 1994; Pini Prato et al., 2000). Often accompanying problems are muscular conditions, parafunctions, and malocclusions (Geiger, 1980, 2001).

Among the acquired causes of recession, it is worth focusing on iatrogenic dental causes, which can be largely prevented by appropriate treatment planning using modern diagnostic techniques (Zachrisson et al., 2007). Exceeding orthodontic boundaries during tooth movements despite unfavorable morphology of the alveolar process can be associated with complications that are difficult to treat. Bone dehiscences and fenestrations are particularly common (Yang et al., 2015). There are also many classifications of alveolar ridge that are used when planning implantoprosthetic treatment. The classification of Cawood and Howell is based on a residual ridge and allows simple communication among clinicians (Cawood and Howell, 1988). Classifications based on alveolar morphology with preserved dentition are less common. Only the analysis of Atwood of the morphology and post-extraction remodeling of the anterior segment of the mandibular alveolar section takes into account the stage I of the developed classification. This stage relates to the toothed ridge together with potential bone defects (Atwood, 1971). However, the author does not distinguish possible types of defects, focusing on the description of bone morphology after extraction. Yang et al. presented a proposal for a new alveolar bone classification, focusing on the assessment of bone defects, mainly dehiscences and fenestrations. They considered that the assessment of these pathologies is important in effective interdisciplinary dental treatment. The authors distinguished three classes: A (I)—dehiscences located on one side of the tooth, B (II)—dehiscences with periapical bone defects located on one side of the tooth, and C (III)—dehiscences located on both sides of the tooth. Within class A, they distinguished three subclasses depending on the severity of bone loss (DI—dehiscences of the coronal one-third of the root, DII—middle one-third, DIII—apical one-third without the involvement of the apical foramen). Three subclasses were also designated in class B. DI stands for dehiscences of the whole root, with the involvement of the apical foramen, DII—dehiscences with separate periapical lesions, and DIII—dehiscences with fenestrations. Class C is dehiscences located on both sides of the tooth (Yang et al., 2015) (Fig. 4).

To analyze the bone width in the vestibular-lingual dimension, direct invasive methods (e.g., using a periodontal probe) and indirect measurements from X-rays are used (Dibart and Dietrich, 2010). Non-invasive methods include ultrasound measurement as well as intraoral two-dimensional imaging (bite-wing, periapical, occlusal) and extraoral cephalometric radiography. On the cephalogram, which is also useful for the assessment of the risk for a recession, the measurement of the angle of bone labial width developed by Dominiak proved to be useful (Dominiak, 2010; Dominiak and Gedrange, 2014). This angle is drawn between the following points: (1) the apex of the most protruded incisal tooth (API), (2) cementoenamel junction (CEJ) minus 2 mm, and (3) mandibular bone point B denoted as a whole by the angle API-CEJ2-B. Measurements based on this type of imaging were associated, however, with limitations such as the overlap of anatomical structures in the sagittal plane and magnification of the image of approximately 3.45%. Thus, three-dimensional computed tomography is the best radiological method that allows accurate qualitative and quantitative assessment of anatomical structures, including the alveolar ridge.

To broaden knowledge in this area, we conducted the study to determine whether a bone deficiency in the anterior mandible is a common problem and to investigate its degree in the population of adults based on analysis of cone-beam computed tomography (CBCT). Own modification of Yang et al. classification of bone defects was proposed (Yang et al., 2015).

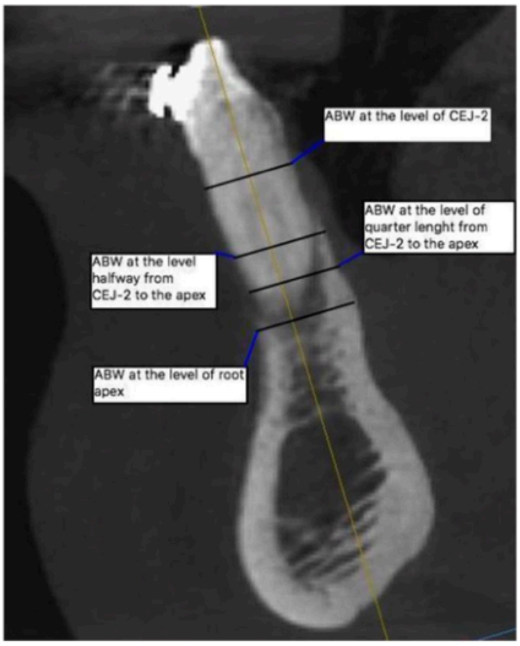


Fig. 1. The alveolar ridge width measurement in relation to the root of the tooth. ABW—alveolar bone width; CEJ-2—cementoenamel junction minus 2 mm.

2. Material and methods

The research material consisted of 100 CBCT scans obtained from the database of private dental practice in Wroclaw, Poland. The analysis covered randomly selected scans of patients (women and men) who underwent radiological examinations for various diagnostic reasons and included at least the anterior mandible region. The analysis included adult (non-growing) patients with preserved dentition at least in the anterior mandible. The exclusion criteria were: systemic diseases and drug treatment that could affect the bone tissue, previous surgical and periodontal treatment concerning anterior mandible, craniofacial anomalies, and previous trauma to the mandible.

All CBCT scans were captured using Pax Flex3D Vatech Computed Tomography X-ray System. For mandible center image: FOV: 80 mm width and 50 mm height or for occlusal center image: FOV: 120 mm width and 85 mm height. Voxel size was 0.200. All images were analyzed using EzDent-i software (Vatech). Analyzed parameters were measured on the sagittal plane in the middle of tooth 31. Only the buccolingual bone dimension was measured on the axial plane. The reference lines were perpendicular to each other, and the vertical line was aligned with the long axis of the tooth as tooth inclination was not determined in the analysis. The graphical presentation of the measurements is depicted in Figs. 1–3 and described below. The alveolar ridge width was measured as follows:

- at the four points in relation to the root of the 31. tooth: at the level of CEJ-2 mm (the crestal bone level of healthy periodontium), at the root apex, in half-length from CEJ-2 to the apex and in the quarter length from CEJ-2 to the apex (Fig. 1);
- at the level of the highest point of the vestibular bone (id1) (Fig. 2);
- at the level of the highest point of the lingual bone (id2) (Fig. 2).

It was determined if there was dehiscence (dehiscence was considered when the marginal bone level was below CEJ-2 mm). Its

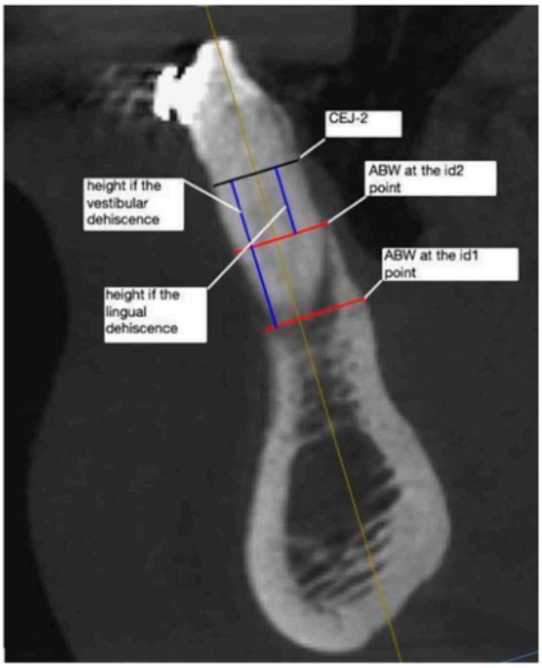


Fig. 2. Measurement of the height of the lingual and vestibular dehiscence as well as alveolar ridge width at the level of the highest point of the vestibular lingual bone. ABW—alveolar bone width; CEJ-2—cementoenamel junction minus 2 mm.

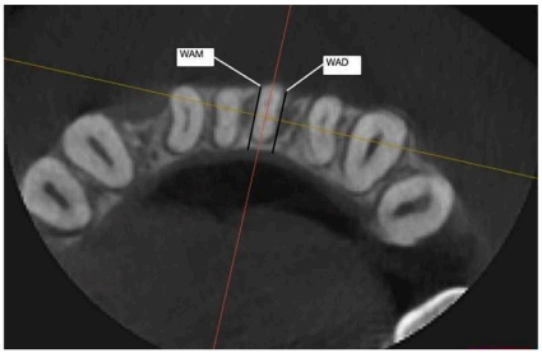


Fig. 3. Measurement of buccolingual dimensions. WAM- width of the alveolar bone mesially; WAD—width of the alveolar bone distally.

height from the vestibular (HDV) and/or lingual (HDL) side was measured (Fig. 2). It was determined whether vestibular and lingual fenestration were present (FV and FL, respectively). In the presence of fenestration, its height was measured (HFV and HFL). Moreover, additional points were marked than at which the width of the alveolar ridge was measured. It was the lowest point within vestibular and lingual fenestration- id3 and id4 respectively. Because of the clinical implications caused by the occurrence of a thin layer of

Table 1
Parameters of the alveolar process of the 31. tooth.

Parameter	Number; Mean ± SD [mm]
Horizontal width of the alveolar process at half distance between CEJ and the root apex on the mesial side	n = 99; 6.25 ± 1.75
Horizontal width of the alveolar process at half distance between CEJ and the root apex on the distal side	n = 99; 6.85 ± 1.73
Alveolar process width at the level of the highest point of the vestibular bone (id1)	n = 100; 7.12 ± 1.63
Alveolar process width at the level of the highest point of the lingual bone (id2)	n = 100; 6.53 ± 1.27
Alveolar process width at the apical border of the vestibular fenestration (if any) (id3)	n = 9; 7.52 ± 1.39
Alveolar process width at the apical border of the lingual fenestration (id4)	n = 0

CEJ, cementoenamel junction.

cortical bone covering the root, this aspect was taken into account separately. In the case of the vestibular and lingual bone layer was <1 mm, this fact was marked separately. The value of this dimension was then determined (HVCL—the height of the vestibular cortical layer and HLCP—the height of the lingual cortical layer). If the level of the marginal bone was below CEJ-2 on both sides (bilateral dehiscence), then the measuring width at this level was equal to the width of the tooth, therefore, the alveolar width value was considered zero. Similarly, in a situation where dehiscence occurred on one side, and the root was covered only with a thin cortical layer (<1 mm) on the other or the root was covered on both sides with a thin cortical layer. The buccolingual dimension at the level halfway from CEJ-2 to the apex was measured. This value was determined in the axial section, mesially and distally to the 31. tooth (WAM- width of the alveolar bone medially and WAD—distally). The buccolingual dimensions are shown in Fig. 3.

Data were statistically analyzed. Descriptive statistics were calculated. The data were presented as means with standard deviations and numbers with percentages. The frequency of the occurrence of fenestrations and dehiscences (categorical variables) in relation to the side (buccal vs lingual) were compared with the Pearson's chi-squared test. The level of statistical significance was set up at $\alpha = 0.05$. Statistical analysis was carried out with the R Project for Statistical Computing v. 3.4.1.

3. Results

The studied sample included 100 patients (100 teeth) aged from 18 to 69 years, with a median of 36 years. The study group included 32 men and 68 women. On all CBCT images, the alveolar process around the 31. tooth was measured. The morphology of the alveolar process is shown in Table 1.

In the study group, fenestration was detected in 9% of study images and dehiscence was detected in 90% of study images. The presence of any bone defect was found in 91 (91%) of cases. A thin alveolar plate of below 0.1 mm independent from the side was found in 43 (43%) of cases. The detailed characteristics of bone

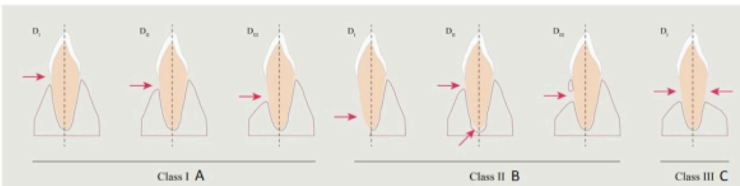


Fig. 4. Yang et al. classification.

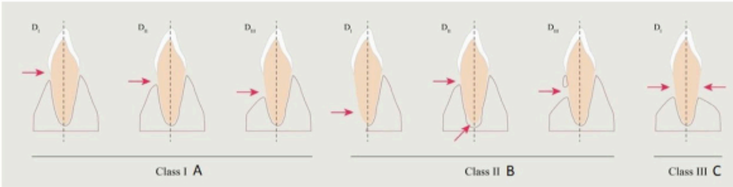


Fig. 5. Own modification of Yang et al. classification-class A (I).

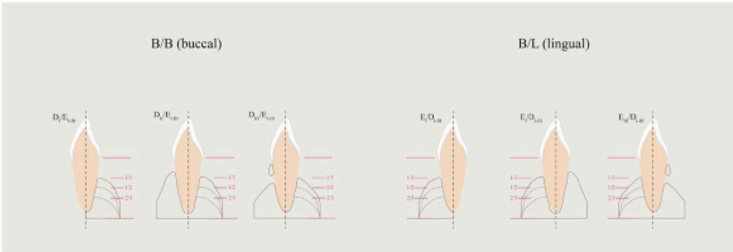


Fig. 6. Modification of Yang et al. class B (II).

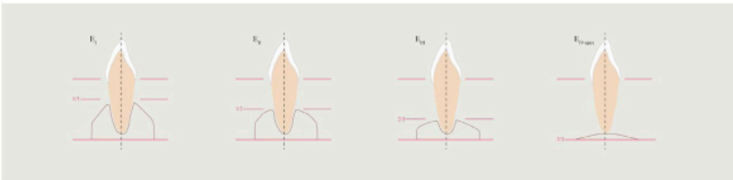


Fig. 7. Modified class C (III).

Table 2
Distribution of alveolar bone defects by type and sex.

	Men (n = 32)	Women (n = 68)	Total (n = 100)
Fenestration (buccal side)	3 (9%)	6 (9%)	9 (9%)
Fenestration (lingual side)	0	0	0
Fenestration (both sides)	0	0	0
Dehiscence (buccal side)	26 (81%)	64 (94%)	90 (90%)
Dehiscence (lingual side)	19 (59%)	53 (78%)	72 (72%)
Dehiscence (both sides)	17 (53%)	50 (74%)	67 (67%)
Plate <0.2 mm (buccal side)	14 (44%)	18 (26%)	32 (32%)
Plate <0.2 mm (lingual side)	6 (19%)	5 (7%)	11 (11%)
Plate <0.2 mm (both sides)	2 (6%)	3 (4%)	5 (5%)

defect occurrence are presented in Table 2. The mean height of buccal fenestration was 3.10 ± 1.09 mm. The mean height of buccal dehiscence was 4.39 ± 1.82 mm and the mean height of lingual dehiscence was 4.27 ± 2.49 mm. The mean height on which the thin alveolar plate was detected on the buccal side was 3.26 ± 1.32 mm and 4.83 ± 1.96 mm on the lingual side. The occurrence of dehiscence on the buccal side was significantly greater than on the lingual side (90% vs 72%; p = 0.001).

Other parameters were also measured. The 31. tooth was measured at several levels. The tooth width at CEJ was 7.52 ± 1.25 mm for cases above 0 mm (n = 45); at half distance between CEJ and the root apex for cases above 0 (n = 88), it was 7.25 ± 1.53 mm; at ¼ of a distance between CEJ and the root apex measured from the apex root (n = 100), it was 7.11 ± 1.72 mm; and at the apex root (n = 100), it was 7.61 ± 1.92 mm. Two systems were used to classify alveolar bone defects: the classification of Yang et al. (Fig. 4). And the modified Yang et al. classification proposed by authors (Fig. 5–8). A comparison of results showed that of 100 cases assessed, 16 received the same score, 46 were described in greater detail, and 38 cases were classified differently (new class). Differences between classifications are depicted in Table 3.

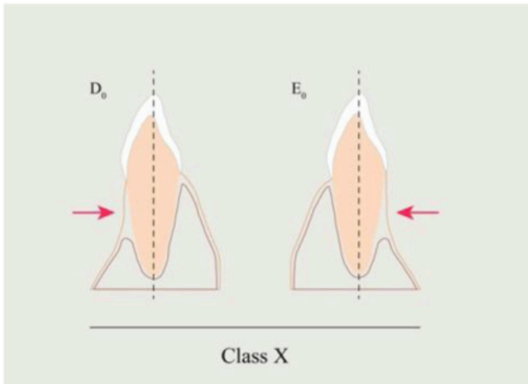


Fig. 8. New class X.

Due to significant clinical implications depending on the degree of bone loss both on the vestibular and lingual sides, class C was modified. Regarding class A (Yang et. al), a modification related to the lingual side of the alveolar ridge was made. Then to the original class A with DI-DIII subclasses (denoting bone loss on one-vestibular side at the level of coronal ⅓ length relative to the root, middle ⅓, and apical ⅓, respectively), additional EI-EIII subclasses, which are the equivalent of unilateral dehiscence, but for the lingual side were added (Fig. 5). Modified class B, also taking into account the degree of bone loss on both sides includes then a B/B (buccal) and B/L (lingual) classes. Class B/B and B/L are mirror images indicating the existence of variants of bone defects on one side as in the original (D for vestibular and E for lingual variants). DI or EI means dehiscence reaching the apical foramen, DII, or EII—dehiscence coexisting with a separate periapical defect, and

Table 3
Comparison between the classification of Yang et al. and the modified classification.

class		subclass	Yang et al.	Dominiak et al.
A		D_{I}	n=18	n=7
		D_{II}	n=6	n=6, n*=3
		D_{III}	n=3	n=3, n*=2
		E_{I}	-	n=1
		E_{II}	-	n=0, n*=4
		E_{III}	-	n=0, n*=2
B	B	D_{I}	n=0	-
		D_{II}	n=0	-
		D_{III}	n=6	-
	B/B	D_{I}/E_{I}	-	n=1
		D_{I}/E_{II}	-	n=0
		D_{I}/E_{III}	-	n=0
		D_{II}/E_{I}	-	n=0
		D_{II}/E_{II}	-	n=0
		D_{II}/E_{III}	-	n=0
		D_{III}/E_{I}	-	n=8
		D_{III}/E_{II}	-	n=1
		D_{III}/E_{III}	-	n=0
	B/L	E_{I}/D_{I}	-	n=2
		E_{I}/D_{II}	-	n=2
		E_{I}/D_{III}	-	n=2
		E_{II}/D_{I}	-	n=0
		E_{II}/D_{II}	-	n=0
		E_{II}/D_{III}	-	n=0
		E_{III}/D_{I}	-	n=0
		E_{III}/D_{II}	-	n=0
		E_{III}/D_{III}	-	n=0
C		E_{I}	n=67	n=6
		E_{II}		n=8
		E_{III}		n=4
		E_{IV}		n=0
X		D_{0}	-	n=27
		E_{0}	-	n=6
		D_{0}/E_{0}	-	n=5
		new class		
		more detailed		
		same		

DIII or EIII—the coexistence of unilateral dehiscence and fenestration. The level of bone loss is always determined for the other side on a three-point scale (EI-III and DI—III—coronal ⅓ of the root length, middle ⅓, and apical ⅓) (Fig. 6). The new class C then includes the EI-EIV subclasses, defining bone loss at the level of the coronal ⅓ concerning the root length, middle ⅓, apical ⅓, and the defect reaching almost to the apex on both sides (~3/3) respectively (Fig. 7). In our analysis, in 11 cases (n* = 11), vestibular and lingual dehiscence coexisted, but were not parallel. We marked them with the symbol *. Three cases were classified as ADII/EI, one as ADIII/EI and one as ADIII/EII. At that time, the greater dehiscence was on the vestibular side. In turn, in 6 cases greater dehiscence was on the lingual side. There were 4 cases of AEII/DI and two AEIII/DI. An additional modification is the introduction of a separate class X (D0 for the vestibular side and E0 for the lingual side) (Fig. 8). This class means that on a given side there is dehiscence that is not visible in the clinical examination. The marginal bone is below the CEJ-2 level, or the root is covered only with a thin cortical plate (<1 mm thick), which has a particular tendency to resorb quickly, but the root and/or a thin plate are covered with the soft tissue. It is an invisible component of the recession according to Geiser et al. (Geiser et al., 1999).

Class A means unilateral dehiscence (DI-DIII of different degrees of advancement for the vestibular and EI–EIII for the lingual one). Class B was divided into B/B and B/L (B-buccal and B-lingual). B/B distinguishes DI—vestibular dehiscence reaches apical foramen, DII—vestibular dehiscence and periapical defect, and DIII—vestibular dehiscence with fenestration. The degree of bone loss of the opposite (lingual) side (EI-EIII) was also determined. B/L is a mirror image. Class C means bilateral (in our modification parallel) bone loss along with the indication of the degree of advancement. Class X means recessions that are not visible in the clinical examination (D0 on the vestibular side and E0 on the lingual side).

4. Discussion

The present study revealed that bone defects in the alveolar process are common. The presence of any bone defect, either dehiscence or fenestration, was found in 91% (n = 91) of cases, while a thin cortical layer of below 0.1 mm was found in 43% (n = 43) of cases. CBCT is a reliable method to detect defects in the alveolar process. It allows for precise measurements of the alveolar bone process in patients suspected to have dehiscences and fenestrations without any distortions as in the case of panoramic images, which is particularly useful before restorative treatment.

Position of teeth together with gingival esthetics contributes not only to the design of smile and overall facial appearance but also is part of oral health (Morley and Eubank, 2001). A desire to look better and healthier is a driver for the interest in restorative procedures. Replacing missing or damaged teeth with implants improves oral health and had a positive impact on overall health, appearance, and self-esteem (Nagahisa et al., 2018). However, implantology is not free from complications that can be minimized by proper qualification to surgery, treatment planning, and management (Chackartchi et al., 2019; Żurek et al., 2016).

In the last decade, technical advances allowed us to develop and use CBCT to measure alveolar defects. Initial attempts used axial and cross-sectional imaging (Enhos et al., 2012), while later, direct measurements in the volume-rendering mode of CBCT was used (Leung et al., 2010). However, Yang et al. brought new insight into classifying alveolar bone defects (Yang et al., 2015).

Although this classification brings valuable input into the assessment of alveolar bone defects, it still is burdened by limitations that we address in the present study. Most of all, the classification of Yang et al. focuses mostly on dehiscences but not fenestrations. For these reasons, we proposed a modified classification based on our clinical experience. It includes 4 additional aspects. Firstly, about the planning and implementation of interdisciplinary dental treatment, it is important to determine the morphology and severity of the bone defect on both the vestibular and lingual sides in each case. As a result, the EI-III subclasses in class A were introduced, recognizing unilateral lingual dehiscence as clinically important as vestibular. In class B, it was also proposed that along with the character of the defects on one side (coexisting dehiscences, fenestrations, and/or periapical defects), the bone level on the opposite side should always be determined, taking into account the lingual side, as before. Therefore, this modification of class B together with the introduction of variants that are its mirror image will allow a much more accurate determination of the morphology of a given region. Class C should provide information on the degree of bone loss (for bilateral, parallel dehiscence), taking into account the particularly difficult clinical situation, where the marginal bone loss almost reaches the root apex. Additionally, the proposed class X is reserved for recessions that are not clinically visible. Our observations show that sometimes the intraoral examination does not reveal significant recessions, and only CBCT imaging reveals dehiscence or only a thin cortical plate covering the tooth root. We consider of a thin cortical layer a separate defect during planning the orthodontic treatment because, on the clinical point of view, such a thin bone layer is prone to resorption (Srebrzynska-Witek et al., 2018). As can be seen in the results, some both classification overlap to a certain extent, but the modified classification describes defects with greater detail. We have taken into account only one tooth — mandibular central incisor (31), while most studies evaluated defects in the alveolar process around many teeth. We chose the lower central incisor because of its anatomical location within the mandibular symphysis (junction of the two parts of which the bone is composed at an early period of life). The medial suture area is often characterized by a very small amount of spongy and/or cortical bone. Teeth crowding are often found in the anterior part of the mandible. Incorrect displacement and position (vestibular or lingual) of anterior teeth results in the occurrence of dehiscence and/or gingival recession. In addition, the cephalogram, on which the incisors overlap, allows to proper assessment only the tooth, which position is mostly vestibular (central incisor). Thus, the analysis consisted of a random selection of one tooth in one patient (100 patients and 100 teeth). In order to obtain comparative values between participants, measurements were taken within the same tooth (31) and at the same reference points. In the study by Yang et al., the first incisors were affected only in 2.87% of cases. This prevalence is low in comparison to both the prevalence of defects around mandibular first premolar (the most frequently affected location) which reached 37.56% (Yang et al., 2015) and the prevalence of either dehiscence or fenestration in the present study, which amounted to 91%. It is worth noting that Yang et al. investigated 2574 teeth in 108 patients and found that 75% of patients had at least one alveolar bone defect (Yang et al., 2015). The age of patients was not provided in this study. Sheng et al. focused on dehiscences and fenestrations in anterior teeth (Sheng et al., 2020). They examined CBCT images of 21 patients (252 anterior teeth) between the ages of 12 and 26 years. Before the orthodontic treatment, the occurrence of any labial bone defect for the mandibular central incisor was 38.10%, while on the lingual side, no fenestrations were detected and dehiscences were found in less than 1% of cases. This combined prevalence of bone defects increased significantly after the orthodontic treatment to 71.42% on the labial side and 45.24% on the lingual side. Evangelista et al. reported that bone defects around the mandibular central incisors (21.05%) were one of the most frequently affected locations, but with the predominance of fenestrations (Evangelista et al., 2010). Their study sample included 79 Class I and 80 Class II Division 1 patients (4319 teeth) with malocclusion. Patients' mean age was 27.09 ± 7.46 and 26.48 ± 8.18 in the two studied groups. In the present study, the majority of the dehiscences were found on the buccal side. Similarly, Yang et al. found that 97% of defects affected buccal alveolar plates, while only 5% were detected on the palatal or lingual side (Yang et al., 2015). Importantly, the total number of teeth analyzed by the above mentioned authors was higher than assessed in our study. However, this differences is smaller regarding the number of CBCT images, because, in our study, we focused only on the anterior mandible due to the significant clinical implications that distinguish it from other parts, particularly in the orthodontic and periodontological. It is especially valuable for orthodontics, as neglecting the morphological assessment of the anterior mandible is often associated with serious complications which are difficult to cure.

The differences in the prevalence of bone defects in the alveolar process vary considerably across studies. One of the factors that increase the occurrence of bone defects is age. In the present study, the median age was 36 years. In the studies of Sheng et al. and Evangelista et al., patients were about 10 years younger (Evangelista et al., 2010; Sheng et al., 2020). Peña-Montero et al. confirmed a relationship between age and the occurrence of fenestrations (Pena-Montero et al., 2016). Orthodontic treatment increases the risk of thinning of the compact bone layer of the alveolar process. A systematic review conducted by Sendyk et al. identified 12 studies on the effect of orthodontic treatment on the condition of the bone (Sendyk et al., 2019). They concluded that such treatment reduces the bone thickness of incisors, predominantly on the palatal side. Jager et al. noted that older age increases chances for greater bone damage during orthodontic treatment with multibracket appliances (Jäger et al., 2017). They reported that in patients over 30 years of age, a more significant vertical bone loss along with a greater dehiscence depth was found.

Taking into account a high prevalence of bone defects and the possibility of further deterioration of the bone condition following orthodontic treatment indicates that there is a need for careful assessment of the alveolar process on different stages of treatment. Particular caution should be paid on adult patients because orthodontic treatment carries a higher risk for bone loss and the development of bone defects. Dominiak and Gedrange presented their own method of three-dimensional reconstruction of the anterior mandibular bone, which is not only a way to treat existing bone defects but also as a prevention of bone loss following interdisciplinary treatment (periodontological, surgical, orthodontic) in order to avoid iatrogenic worsening of existing conditions. The authors pointed out the importance of making measurements based on radiographs. The obtained values allow for proper assessment of the local condition before treatment, accurate planning of treatment as well as the assessment of the effectiveness of comprehensive therapy (Dominiak and Gedrange, 2014). The angle of buccal bone thickness (API-CEJ2-B) mentioned earlier allows the estimating and prediction of the risk of recessions development. It has been proven that lower values of this angle ($<16^\circ$) are associated with a greater risk of recession. Angle values may vary depending on the treatment, mainly orthodontic (Warmuz et al., 2014). Bone reconstruction in the area of the mandibular symphysis results in an increase in this angle, which reduces the risk of recession. Our modification of the Yang classification together with proper measurements and assessment of alveolar bone and soft tissues could be helpful when evaluating the severity of the bone defect, planning interdisciplinary treatment within safe boundaries as well as when planning any reconstructive procedures. Bone deficiency in the anterior mandible is a common problem in adults. An attempt to restore the correct morphology of the alveolar process after improper treatment, especially orthodontic, constitutes a therapeutic challenge. The frequent occurrence of bone deficiency prompts establishing safe treatment planning strategies (Warmuz et al., 2016). If tissue deficiency is found, an effective alveolar process reconstruction method should be developed to ensure therapeutic success with minimizing side effects and implemented before further orthodontic treatment.

5. Conclusions

Careful assessment of the alveolar process supported by the comprehensive classification of bone defects may facilitate communication between the treating specialist and support better treatment planning.

Ethical statement

Ethical approval was obtained from the Commission of Bioethics at Wroclaw Medical University, Wrocław, Poland.

Conflict of interest

All authors declare no conflict of interest.

Funding

No funding received for this study.

References

Atwood, D.A., 1971. Reduction of residual ridges: a major oral disease entity. J. Prosthet. Dent. 26, 266–279.
Cawood, J.I., Howell, R.A., 1988. A classification of the edentulous jaws. Int. J. Oral Maxillofac. Surg. 17, 232–236.
Chackartchi, T., Romanos, G.E., Sculean, A., 2019. Soft tissue-related complications and management around dental implants. Periodontology 2000 81, 124–138.
Dibart, S., Dietrich, T., 2010. Practical Periodontal Diagnosis and Treatment Planning. Wiley-Blackwell, Ames, Iowa.
Dominiak, M., 2010. Own Method of Estimation of Prognostic Gingival Recession. Monography of Habilitation. AM, Wrocław.
Dominiak, M., Gedrange, T., 2014. New perspectives in the diagnostic of gingival recession. Adv. Clin. Exp. Med. 23, 857–863.
Enhos, S., Uysal, T., Yagci, A., Veli, I., Ucar, F.I., Ozer, T., 2012. Dehiscence and fenestration in patients with different vertical growth patterns assessed with cone-beam computed tomography. Angle Orthod. 82, 868–874.
Evangelista, K., Vasconcelos, Kd.F., Bumann, A., Hirsch, E., Nitka, M., Silva, M.A.G., 2010. Dehiscence and fenestration in patients with Class I and Class II Division 1 malocclusion assessed with cone-beam computed tomography. Am. J. Orthod. Dentofac. Orthop. 138, 133.e131–133.e137.
Geiger, A.M., 1980. Mucogingival problems and the movement of mandibular incisors: a clinical review. Am. J. Orthod. 78, 511–527.
Geiger, A.M., 2001. Malocclusion as an etiologic factor in periodontal disease: a retrospective essay. Am. J. Orthod. Dentofacial Orthop. 120, 112–115.
Geiser, E., Kleisner, J., Marinello, C.P., 1999. Gingivale Rezession. Eine Ubersicht uber Pravalenz, Atiologie und Klassifikation. Schweiz Monatsschr Zahnmed 130, 1279–1284.
Handelman, C.S., 1996. The anterior alveolus: its importance in limiting orthodontic treatment and its influence on the occurrence of iatrogenic sequelae. Angle Orthod. 66, 95–109, discussion 109–110.
Jäger, F., Mah, J.K., Bumann, A., 2017. Peridental bone changes after orthodontic tooth movement with fixed appliances: a cone-beam computed tomographic study. Angle Orthod. 87, 672–680.
Leung, C.C., Palomo, L., Griffith, R., Hans, M.G., 2010. Accuracy and reliability of cone-beam computed tomography for measuring alveolar bone height and detecting bony dehiscences and fenestrations. Am. J. Orthod. Dentofacial Orthop. 137, S109–S119.
Miller Jr., P.D., 1985. A classification of marginal tissue recession. Int. J. Periodontics Restorative Dent. 5, 8–13.
Morley, J., Eubank, J., 2001. Macroesthetic elements of smile design. J. Am. Dent. Assoc. 132, 39–45.
Nagahisa, K., Arai, K., Baba, S., 2018. Study on oral health-related quality of life in patients after dental implant treatment with patient-reported outcome. Int. J. Oral Maxillofac. Implants 33, 1141–1148.
Newman, G.V., Goldman, M.J., Newman, R.A., 1994. Mucogingival orthodontic and periodontal problems. Am. J. Orthod. Dentofacial Orthop. 105, 321–327.
Pena-Montero, C.A., Rivas-Gutierrez, R., Sierra-Rosales, E., Diaz-Pena, R., 2016. Maxillary bone defects and their relationship to transverse maxillary discrepancies. APOS 6, 251–255.
Pini Prato, G., Baccetti, T., Giorgetti, R., Agudio, G., Cortellini, P., 2000. Mucogingival interceptive surgery of buccally-erupted premolars in patients scheduled for orthodontic treatment. II. Surgically treated versus nonsurgically treated cases. J. Periodontol. 71, 182–187.
Sendyk, M., Linhares, D.S., Pannuti, C.M., Paiva, J.Bd., Rino Neto, J., 2019. Effect of orthodontic treatment on alveolar bone thickness in adults: a systematic review. Dental Press J. Orthod. 24, 34–45.
Sheng, Y., Guo, H.M., Bai, Y.X., Li, S., 2020. Dehiscence and fenestration in anterior teeth: comparison before and after orthodontic treatment. J. Orofac. Orthop. 81, 1–9.
Srebrzynska-Witek, A., Koszowski, R., Rozylo-Kalinowska, I., 2018. Relationship between anterior mandibular bone thickness and the angulation of incisors and canines—a CBCT study. Clin. Oral Investig. 22, 1567–1578.
Warmuz, J., Puszkiel, P., Botzenhart, U., Gedrange, T., Dominiak, M., 2014. Practical application of a method for assessing the progression of gingival recessions in orthodontically treated patients—a pilot study. Oral Health Dent. Manag. 13, 772–778.
Warmuz, J., Jagielak, M., Botzenhart, U., Seeliger, J., Gedrange, T., Dominiak, M., 2016. Influence of morphological parameters on the development of gingival recession in class III malocclusion. Ann. Anat. 206, 64–72.
Wehrbein, H., Bauer, W., Diedrich, P., 1996. Mandibular incisors, alveolar bone, and symphysis after orthodontic treatment. A retrospective study. Am. J. Orthod. Dentofacial Orthop. 110, 239–246.
Yang, Y., Yang, H., Pan, H., Xu, J., Hu, T., 2015. Evaluation and new classification of alveolar bone dehiscences using cone-beam computed tomography in vivo. Int. J. Morphol. 33, 361–368.
Zachrisson, B.U., Nyoygaard, L., Mobarak, K., 2007. Dental health assessed more than 10 years after interproximal enamel reduction of mandibular anterior teeth. Am. J. Orthod. Dentofacial Orthop. 131, 162–169.
Żurek, J., Dominiak, M., Tomaszek, K., Botzenhart, U., Gedrange, T., Bednarz, W., 2016. Multiple gingival recession coverage with an allogeneic biostatic fascia lata graft using the tunnel technique—a histological assessment. Ann. Anat. 204, 63–70.

8.2. Publikacja 2: Advancements in alveolar bone reconstruction: A systematic review of bone block utilization in dental practice.

AHEAD OF PRINT

Review

Advancements in alveolar bone reconstruction: A systematic review of bone block utilization in dental practice

Sylwia Hnitecka[1,A–F], Cyprian Olchowy[2,A,E,F], Anna Olchowy[3,B,D,F], Paweł Dąbrowski[4,B,D,F], Marzena Dominiak[5,A,E,F]

[1] Clinical Department of Maxillofacial Surgery, Wroclaw Medical University, Poland
[2] Collegium Medicum, Jan Dlugosz University in Czestochowa, Poland
[3] Department of Experimental Dentistry, Wroclaw Medical University, Poland
[4] Division of Anatomy, Department of Human Morphology and Embryology, Wroclaw Medical University, Poland
[5] Department of Dental Surgery, Wroclaw Medical University, Poland

A – research concept and design; B – collection and/or assembly of data; C – data analysis and interpretation;
D – writing the article; E – critical revision of the article; F – final approval of the article

Dental and Medical Problems, ISSN 1644-387X (print), ISSN 2300-9020 (online) *Dent Med Probl.*

Address for correspondence
Cyprian Olchowy
E-mail: cyprian.olchowy@gmail.com

Funding sources
None declared

Conflict of interest
None declared

Acknowledgements
None declared

Received on November 28, 2023
Reviewed on December 5, 2023
Accepted on January 16, 2024

Published online on May 23, 2024

Cite as
Hnitecka S, Olchowy C, Olchowy A, Dąbrowski P, Dominiak M. Advancements in alveolar bone reconstruction: A systematic review of bone block utilization in dental practice [published online as ahead of print on May 23, 2024]. *Dent Med Probl.* doi:10.17219/dmp/181532

DOI
10.17219/dmp/181532

Abstract

Alveolar reconstructive surgery employs a variety of surgical techniques and biomaterials, with a particular focus on bone blocks as a crucial methodology for restoring and augmenting deficient bone structures. Bone blocks are often employed to support periodontal health or as a foundation for future prosthetic rehabilitation with dental implants. This systematic review investigated recent advances in bone blocks for alveolar bone reconstruction, comparing autologous, allogeneic and xenogeneic types. A search of PubMed identified 56 records, of which 21 were included in the qualitative analysis. The studies involved 685 patients in total. Bone blocks are pivotal for three-dimensional bone regeneration, providing a stable scaffold for achieving the desired bone volume during healing. Autologous bone, harvested from the patient, boasts high biocompatibility, excellent osteogenic properties and minimal immunologic risks. However, its drawbacks include the need for an additional surgical site and extended procedural times. Allogeneic bone blocks involve transferring bone between individuals, offering increased graft availability and customization options without requiring a second surgical site. However, they exhibit moderate resorption rates and carry a heightened risk of immunologic reactions and disease transmission. Innovative techniques, such as tunneling, laser osteotomy, graft customization, and platelet-rich fibrin (PRF) application on wound during surgical treatment show promise in enhancing alveolar bone reconstruction efficacy. In conclusion, despite the traditional preference for autologous bone, the review suggests that alternative materials, particularly individualized allogeneic bone blocks, coupled with modern techniques, could emerge as a standard procedure for regenerating alveolar bone defects due to their satisfactory results and potential advantages.

Keywords: alveolar bone loss, allografts, bone regeneration, bone block, reconstruction

Introduction

The jawbones, including the mandible and maxilla, may be affected by a number of conditions. Such conditions can be extensive, as in the case of trauma or infection, or localized, as is the case with tumors and cysts. Iatrogenic defects may develop as a consequence of applied treatments, such as radiotherapy of malignant lesions.[1] The jawbones can be affected in the course of chronic and general diseases, including osteoporosis and osteomyelitis. Congenital causes include developmental anomalies that may impact the normal growth and formation of the jawbones.[2] The frequency of jawbone-related issues in clinical dental practice varies based on patient demographics, oral hygiene practices and general health. The prevalence of bone defects is considerable, reaching 91%, and underscores the significance of research in the field of alveolar bone reconstruction.[3] Treatment of bone defects is also differentiated. It may include surgical augmentations to protect against additional bone loss and to secure the capacity for future implantation.[2]

Bone blocks play a key role in alveolar bone reconstruction, providing a reliable methodology for the restoration and augmentation of deficient bone structures.[4] Bone blocks have gained significant attention and popularity due to their ability to overcome donor site morbidity and achieve high survival rates. Regenerated tissues play a crucial role in achieving stable, long-term implant rehabilitation, enhancing bone remodeling, and minimizing factors such as early marginal bone loss and inflammation.[5,6] Different regenerative methods can be used for alveolar ridge or bone reconstructions, ranging from minor augmentations with bone or bone substitute particles to extensive reconstructions with microsurgical free flaps.[7,8] A variety of surgical techniques and biomaterials are employed in alveolar reconstructive surgery.[9] The majority of augmentations are performed to maintain the condition of the periodontium (e.g., augmentation of periodontal defects, guided bone regeneration) or to prepare a future prosthetic base for rehabilitation with the use of dental implants.[8] In cases of severe sagittal discrepancies between the maxilla and mandible resulting in bone defects, orthodontic treatment alone may not be sufficient.[10] Reconstructing the vertical dimensions of the teeth area in patients with preserved dentition to prevent progressive loss of tooth support structures poses its own set of challenges.[11] A multidisciplinary approach, involving a surgical, orthodontic and periodontal team is essential for the customized treatment of such cases apart from the application of standard treatment methods. When selecting a surgical technique and material, several factors should be considered. These include the location and size of the defect, the properties of the biomaterial and the ease of obtaining it. Additionally, cost, ease of use, stability, and maintenance of the recipient site are crucial considerations. It is important to be aware of the potential complications associated with selecting a specific treatment method. Moreover, ssessing the long-term effects of the chosen surgical approach and biomaterial is essential. A comprehensive evaluation of these factors is necessary to make an informed decision in clinical practice.

The regeneration of vertical bone defects caused by periodontitis is typically straightforward and tends to yield predictable outcomes. Similarly, augmenting a post-extraction socket or addressing a small defect after removing an osteolytic lesion is not demanding.[12,13] However, addressing advanced three-dimensional defects poses a significant challenge. Horizontal regeneration in such cases is frequently unpredictable, and attempts at vertical reconstruction often result in less satisfactory outcomes.[10] The process of three-dimensional bone regeneration relies on establishing a stable scaffold to achieve the desired bone volume during the healing phase.[14] Clinicians commonly employ barrier membranes, including stiffer, non-absorbable, personalized membranes[9] or the increasingly popular bone blocks for this purpose. The implementation of these techniques involves the use of pins or mesh for fixation, and in many instances, biomaterial granules are applied to fill the voids.[15,16]

Bone blocks have a long history of use, and the existing literature contains numerous reports detailing their indications, methods of use and effects.[17,18] These involve the use of various graft types, including autologous, allogeneic, xenogeneic, and synthetic bone substitutes. These grafts act as scaffolds for new bone formation, promoting osteoinduction, osteoconduction and osteogenesis to restore natural bone structures.[19] The biomaterial market has experienced significant growth, offering surgeons a range of bone substitutes with similar properties. Despite the potential to choose and combine these substitutes for effective reconstructions with minimal morbidity and rapid healing, variations exist among the most commonly used substitutes in terms of their chemical, physical and morphological features.[20] While undoubtedly serving as an excellent scaffold for bone reconstruction, the selection of this reconstructive technique should consider factors such as the choice of biomaterial and other potential aspects to enhance the treatment process and achieve the best possible outcome.[10] This systematic review aimed to investigate recent advances in the use of bone blocks in oral surgery. Qualitative data synthesis was used to compare different types of bone blocks: autologous, allogeneic and xenogeneic. Furthermore, the objective was to explore contemporary methods designed to enhance the effectiveness of these procedures.

Material and methods

A systematic search was conducted in PubMed, and a manual search of review papers identified during the search was also performed. The search was conducted in accordance with the Preferred Reporting Items for

Systematic Reviews and Meta-Analyses (PRISMA) statement,[21] on November 17, 2023. The electronic search was constructed using the Medical Subject Headings (MeSH) term "Alveolar Bone Loss/Surgery" and the text word "bone block". The search was limited to studies involving adult participants and articles published in English. However, no restrictions were imposed on geographical scope. The inclusion and exclusion criteria were developed in accordance with the Population, Intervention, Comparison, Outcomes, and Study Design (PICOS) framework.[22] All eligibility criteria are outlined in Table 1.

Two reviewers were involved in the screening process, and any discrepancies were resolved through mutual agreement. In cases where a consensus could not be reached, a third independent reviewer was consulted to make the final decision. The data extraction process was carried out by a single reviewer, and then cross-verified by a second reviewer.

Results

Characteristics of patients and study procedure

The PubMed search identified 56 records, of which 21 were included in the qualitative analysis. The studies were relatively small, with sample sizes ranging from 8 to 101 participants, and involved a total of 685 patients. The majority of studies ($n = 9$) were conducted in Italy. Two studies each originated from Brazil, China, Sweden, and Israel, while 1 study each came from Spain, Portugal, Egypt, and the Netherlands. The study selection process is presented in Fig. 1.

The studies were categorized according to the type of bone biomaterial into autologous,[23–38] allogeneic[39–41] and xenogeneic[26,31,33,34,42] groups to facilitate the description of each type. It should be noted that a single study may investigate more than 1 type, which allows for a comprehensive description of each. Figure 2 depicts the characteristics of different types of bone blocks.

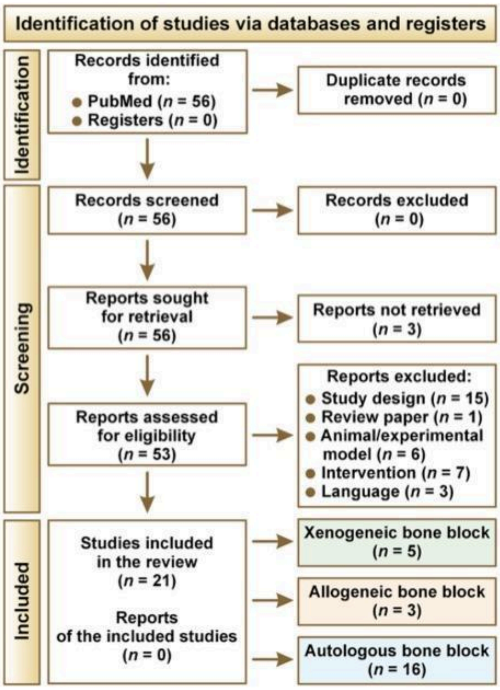


Fig. 1. Flow chart of the study in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement[21]

Autologous bone blocks

Autologous bone refers to bone tissue harvested from the same patient. The procedure for bone reconstruction using autologous bone blocks involves harvesting the block, shaping or fitting it, and placing and fixing it in the defect in a single operation. Autologous grafts for the reconstruction of the jawbones can be obtained from intraoral or extraoral donor sites.[2,27] Intraoral sites are considered more suitable for graft harvesting due to the absence of scarring on the skin and reduced graft resorption, attributed to the similarity in embryological origin and microarchitecture.

Table 1. Eligibility criteria according to the Population, Intervention, Comparison, Outcomes, and Study Design (PICOS) framework[22]

PICOS	Inclusion criteria	Exclusion criteria
Population	– otherwise healthy individuals with alveolar bone deficiency that does not allow placement of dental implants – adults (≥18 years of age)	– patients with chronic diseases
Intervention	alveolar ridge augmentation/reconstruction with a bone block graft	–
Comparison	different types of bone block grafts with the focus on the source of the graft material, i.e., autologous, allogeneic and xenogeneic grafts	–
Outcomes	– efficacy outcomes – safety outcomes	–
Study design	– comparative study – cohort study	– experimental/animal study – case report – proof-of-concept study – review

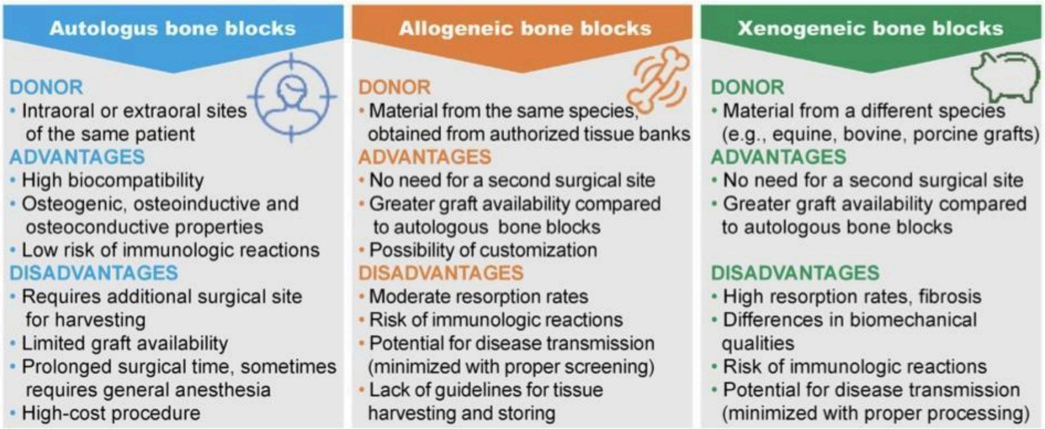


Fig. 2. Characteristics of bone blocks according to the biomaterial type

With regard to extraoral donor sites, bone can be harvested from the calvarium, anterior iliac crest, tibia, fibula, rib, and olecranon (proximal ulna).[26,28,30–33,35] Intraoral donor sites encompass the mandible (chin/symphysis, ramus, retromolar area), zygoma and maxilla (tuberosity).[23–25,29,34,36–38,43,44] With regard to one of the most common donor sites, the mandible, the utilization of the ramus as a donor site, as opposed to the symphysis, has been associated with several advantages. These include increased postoperative comfort and a lower risk of paresthesias, pulp necrosis of the inferior incisors, and labial ptosis.

The key factors for the successful incorporation of a bone block include the preparation of the recipient site and the effective adaptation of the bone blocks.[31] Autologous bone blocks are typically harvested subperiosteally with sufficient visualization of the donor site. This involves identifying crucial nearby anatomic structures, particularly neurovascular bundles and dental roots, and the implementation of adequate protection measures for these structures, in conjunction with the surrounding soft tissue. Subsequently, the osteotomy process, which involves cutting the bone, is performed, followed by the release of the graft. In order to ensure proper contouring of the graft, its size should be 2 mm larger than the size of the defect. Graft osteotomies are commonly executed using saw disks. The osteotomies are then connected, and the graft is elevated using a chisel and hammer.[38] Subsequently, the block must be shaped and contoured under abundant irrigation. Round fissure burs are commonly employed for this purpose, facilitating the removal of all sharp edges. The prepared graft is then stored in a cold, sterile aqueous solution of 0.9% sodium chloride until the recipient site is ready. It is crucial to consistently monitor the fit of the block and its adhesion to the bone surface at the recipient site. If needed, reshaping may be necessary. The adapted block is secured with bicortical titanium screws, which are applied using either a hammer or a screwdriver.[37,40] An alternative method involves the use of resorbable pins in the BoneWelding® technique. In this method, a resorbable pin is applied using ultrasound and heating during insertion into the drill hole. The pin penetrates the drill hole and subsequently melts laterally into the spongy bone structures beneath the cortical bone layer.[45]

Advantages and disadvantages of autologous bone blocks

The primary advantage of autologous bone blocks is a diminished risk of immune rejection, as the graft material originates from the same individual. This results in the graft material possessing good osteogenic, osteoinductive and osteoconductive properties.[2] Autologous bone blocks are considered a safe and reliable method, offering good long-term stability with minimal resorption and donor-site morbidity. The vital properties and the ability of the bone block to function as a scaffold for neoangiogenesis and tissue ingrowth, in addition to providing immediate mechanical stability, contribute to the smooth incorporation, healing and success of the bone graft.[29,34]

Autologous block grafts, sourced from the patient's own bone, typically exhibit lower resorption rates in comparison to allogeneic and xenogeneic grafts.[26] However, it is important to note that higher rates of resorption have been observed with autologous bone blocks derived from the iliac crest.[33] Nevertheless, some researchers have reported similar rates of volume gain regardless of the donor site.[36] Harvesting autologous bone carries a certain risk of donor site morbidity, which is applicable to both extraoral and intraoral donor sites. The complication rates are comparable across different donor sites, and in the majority of patients, healing proceeds uneventfully.[28] While patients generally experience infrequent and minor side effects, they can be as high as 35.7% for calvarial grafts and 33.3% for iliac crest grafts.[46] Bone harvesting from an intraoral site may lead to numbness of the teeth, neurosensory disturbances, postoperative discomfort, and aesthetic issues such as contour changes and soft tissue recession. On the other hand, bone harvesting from an extraoral site is associated with a number of complications, including scarring, postoperative pain, hematomas, delayed muscle motility, the risk of cutaneous nerve injury, and higher hospitalization costs.[28,47–49] Furthermore, general anesthesia, particularly when grafts are harvested from calvarial donor sites,[30,32] may result in increased stress for patients, leading to increased postoperative pain and an extended hospital stay.[42]

Differences between cancellous and cortical autografts should be considered in the decision-making process for managing bone augmentation. The process of molding can pose a challenge when using autologous bone grafts, particularly with cortical autografts, which are less vascularized and more rigid. This characteristic increases the risk of cracking or fracturing the bone graft. However, this risk can be mitigated by the use of custom-made guides.[30]

Allogeneic bone blocks

Allogeneic bone blocks entail the transfer of bone from one individual to another, which involves an exchange of genetic material between different people. Allografts contain numerous chemical domains, endothelial cells and growth factors within the bone matrix released during resorption by osteoclasts. Additionally, allograft bone contains a small amount of bone morphogenic protein with osteoinductive properties.[50] As demonstrated by scanning electron microscopy (SEM), the morphology of the material surface can vary depending on the biobank. Materials sourced from cancellous bone exhibit a spongy structure with holes ranging from 100 to 350 μm in diameter. The surface is smooth, without collagen fibers. In the material sourced from cortical bone, small osteocyte canaliculi holes with an average diameter of 38 μm occur. The bone surface surrounding these holes is smooth, predominantly consisting of strongly bonded collagen fibers, with microcracks and layered particles across the entire surface.[20] The potential for antigenicity in allografts may not be entirely eliminated, as the formation of alloantibodies can complicate bone transplantation. Nevertheless, the quantification of major histocompatibility complex (MHC) molecules in various allogeneic bone grafting materials for alveolar ridge reconstruction revealed trace amounts of MHC molecules. These quantities are considered clinically irrelevant, and there is no evidence of late complications or rejections in clinical practice.[51]

Despite the relatively low risk of antigenicity and potential disease transmission, the significance of allografts increases due to constraints in the size of autologous block grafts from intraoral and extraoral sites. The associated morbidity with graft harvesting often restricts the range of treatment options and may influence patient acceptance.[41,50,52]

In terms of the efficacy of allogeneic bone blocks, while autologous bone block grafts are considered the gold standard in oral surgery, bone substitutes like bone allografts demonstrate comparable effectiveness. There were no significant differences observed in the rate of bone formation between allogeneic materials and autologous bone in maxillary sinus lift procedures.[53] Stability for subsequent fixed prosthetic rehabilitation was ensured when utilizing fresh-frozen iliac crest allografts for augmenting the atrophic maxilla. In addition, allogeneic bone grafts exhibited low resorption rates at 5 months.[41] The maintenance of consistent histological, histomorphometric and immunohistochemical features, along with the preservation of good vascularization, was observed in several studies.[39–41] Finally, allografts represent the optimal choice in terms of safety, as the use of allogeneic bone blocks eliminates donor site morbidity and allows for the acquisition of bone material from tissue banks.[41]

Xenogeneic bone blocks

Bones from various animal species, known as xenogeneic grafts, have been explored as an alternative to allografts due to the financial implications associated with the latter. However, they are used infrequently due to high immunogenicity, inadequate biomechanical qualities and the occurrence of foreign body reactions.[50] In contrast to human bone, the SEM images of animal-bone-derived material reveal a rough surface characterized by statically aggregated particles arranged in a two-stage structure. The first stage comprises particles with an average diameter of 0.353 μm, while the second stage involves larger particles with an average size of 1.395 μm. The material displays particle holes and pores, which increases its overall surface area.[20]

Xenogeneic bone blocks exhibit lower efficiency than other types of bone blocks. In an experimental model, after a 6-month healing period, the alveolar ridge was integrated into the target area.[54] However, significant peripheral resorption was observed, resulting in approx. 30% height and 50% length replacement with connective tissue. Furthermore, grafts containing a cancellous bovine bone mineral scaffold maintained their dimensions, with only moderate new bone formation observed at the graft base.[54] However, some researchers have reported favorable outcomes with the use of xenogeneic bone blocks. In a study involving 20 subjects, the success rate of the interpositional technique using cancellous equine bone blocks appeared to be higher than that of autologous onlay blocks, with an overall success rate of 93.8% for the interpositional technique compared to 82.4% for the onlay technique.[26] In another small study involving 15 patients with single or multiple tooth gaps and severe horizontal collapse of the alveolar ridge, a novel collagenated xenogeneic bone block demonstrated substantial gains in horizontal crestal width. However, this approach was associated with an increased risk of soft tissue dehiscence and early implant loss.[55]

Discussion

Grafting bone blocks is a novel technique with a limited number of large-scale studies. In our review, we identified several proof-of-concept studies and case reports. These preliminary investigations were designed to demonstrate the feasibility and viability of specific methods of block bone grafting and provide evidence that such methodologies are safe and effective in alveolar bone augmentation. Such studies are frequently conducted in the early stages of research to assess the potential efficacy of the treatment of bone defects. Furthermore, case reports were equally prevalent, indicating that considerable research is currently in the pilot stages of bone grafting. Our systematic review was intentionally focused, with the search limited to a single MeSH term. We aimed to identify a comprehensive range of alveolar bone reconstruction methodologies over time while limiting the inclusion of papers that repeatedly evaluated similar approaches.

The feasibility and safety demonstrated in the preliminary investigations of grafting bone blocks from various sources suggest potential advancements in alveolar bone augmentation, with significant implications for clinical practice. It is recommended that clinicians adopt a cautious approach to these emerging technologies, anticipating further research to establish their efficacy and broader applicability in routine clinical settings. Alongside advancements in bone grafting, new techniques are being developed to enhance their effectiveness. This review will discuss tunneling techniques, Er:YAG laser osteotomy, customization, and the supplementary use of platelet-rich fibrin (PRF). The ease of implementation and benefits for patients will be highlighted. These techniques were partially employed by the authors of the identified studies.

Tunneling techniques

Tunneling techniques have been used to increase the effectiveness of bone augmentation procedures conducted with diverse bone sources. This approach minimizes the necessity for extensive soft tissue reflection, potentially reducing surgical trauma and promoting faster healing. The technique involves creating a tunnel or channel in the recipient site's bone without fully exposing it, and then passing the bone graft material through this tunnel to the desired location.[29] The data suggests that employing a tunneling technique enhances bone formation in the context of xenogeneic bone block placement for vertical ridge augmentation. A study comparing flap and tunneling procedures for vertical ridge augmentation using xenogeneic bone blocks in a canine mandible model revealed that the tunneling group exhibited significantly greater new bone formation within the graft sites (46.6 ±23.4%) compared to the flap group (15.3 ±6.6%).[56] In clinical settings, the management of alveolar crest vertical defects in 10 patients using the tunneling technique and autologous bone blocks before the implant resulted in all individuals healing without complications. The study demonstrated a mean overall vertical bone remodeling of 0.55 ±0.49 mm (8.4%) after 8 months, thereby confirming the efficacy of this minimally invasive approach for bone regeneration in vertical defects.[29]

Er:YAG laser osteotomy

In the regeneration of alveolar bone using autologous bone blocks, the harvesting technique is of paramount importance. Inappropriate osteotomy techniques may result in mechanical and thermal damage, impacting the bone's vital potential. While standard methods involving saws, drills and burs are associated with disadvantages such as a limited cut geometry and a risk of soft tissue injury, laser ablation presents advantages like unconstrained positioning, allowing for precise osteotomy without mechanical pressure or stress on the bone. The potential benefits of laser ablation in overcoming limitations associated with traditional osteotomy methods in oral surgery translate into improved efficiency in clinical practice.[57] A pilot study evaluated the feasibility, benefits and limitations of using a variable square pulse Er:YAG laser for harvesting intraoral bone grafts. The results demonstrated excellent cutting efficiency with minimal damage to adjacent soft tissues and no impairment of wound healing. However, limitations, such as the difficulty in achieving a well-defined osteotomy line without irregularities and the necessity for careful laser beam positioning, suggest that the use of an Er:YAG laser may be most appropriate for regions where safe and fixed guidance of the laser beam is feasible. A meta-analysis was conducted to evaluate complications and donor site morbidity, which confirmed the growing utilization of Er:YAG lasers. Patients expressed satisfaction with the graft harvesting method, with higher acceptance reported for procedures involving harvesting from the ascending mandibular ramus.[58]

Customization

In the customization of the bone augmentation procedure for a single-tooth restoration, advanced backward planning can be used, involving preprosthetic bone and soft tissue augmentation. The treatment plan involves manufacturing an allogeneic bone block, which is a collaborative effort between the dentist, the implantologist and the dental laboratory. The optimal implant position and necessary block volume were determined using cone-beam computed tomography (CBCT) data and three-dimensional planning tools. A customized block graft, comprising processed freeze-dried cancellous bone from living donors, was obtained during arthroplasty surgery. The procedure can be supported by soft tissue optimization and tunneling of the recipient gingiva during implantation.[59] In terms of treatment expenses, both the use of stereolithographic models and computer-aided design (CAD) have been shown to improve individualization and increase costs. However, these additional costs can be balanced by reduced surgery time. It should be noted that while there will be an increase in material expenses, when compared to autologous bone blocks harvested from extraoral donor sites, the overall treatment costs may appear significantly lower. Additionally, the surgical procedure for using customized allogeneic bone blocks might be simpler than trimming and adapting autologous bone blocks.

Platelet-rich fibrin

Autologous PRF is widely utilized in oral surgery. This is a blood-derived material, processed from whole blood containing high platelet and growth factor concentrations.[60] While primarily employed to alleviate pain, reduce edema and expedite healing after tooth extractions,[61] researchers are exploring its potential in reconstructive surgery.[62] Notably, key features of PRF include enhanced healing, improved graft stability, and acting as a natural scaffold, facilitating bone graft integration and improving the condition of adjacent tissues. These properties, coupled with PRF's ability to reduce inflammation, increase vascularization and potentially enhance bone density, make it a promising material for alveolar bone reconstruction and augmentation.[26,63]

Conclusions

Autologous bone has traditionally been considered the gold standard due to its inherent properties. However, the need for a second surgical site, increased discomfort, potential complications, intraoperative shaping, and extended surgical time raise the question of whether alternative materials could offer a better solution. Allogeneic blocks lack osteogenic properties, yet their final treatment results are often satisfactory. Overcoming the drawbacks associated with autologous blocks, such as low patient comfort and prolonged procedure time through modern techniques for individualizing blocks, raises the question of whether individualized allogeneic bone blocks could become the new gold standard.

Ethics approval and consent to participate

Not applicable.

Data availability

The datasets generated and/or analyzed during the current study are available from the corresponding author on reasonable request.

Consent for publication

Not applicable.

ORCID iDs

Sylwia Hnitecka https://orcid.org/0000-0002-1171-9817
Cyprian Olchowy https://orcid.org/0000-0002-6559-3973
Anna Olchowy https://orcid.org/0000-0002-5601-7173
Paweł Dąbrowski https://orcid.org/0000-0001-6016-9201
Marzena Dominiak https://orcid.org/0000-0001-8943-0549

References

1. Zehr LJ, Cooper JS. *Mandible Osteoradionecrosis*. Treasure Island, FL: StatPearls Publishing; 2023. PMID:28613667.
2. Bernardi S, Macchiarelli G, Bianchi S. Autologous materials in regenerative dentistry: Harvested bone, platelet concentrates and dentin derivates. *Molecules*. 2020;25(22):5330. doi:10.3390/molecules25225330
3. Dominiak M, Hnitecka S, Olchowy C, Olchowy A, Gedrange T. Analysis of alveolar ridge width in an area of central lower incisor using cone-beam computed tomography in vivo. *Ann Anat*. 2021;236:151699. doi:10.1016/j.aanat.2021.151699
4. Tolstunov L. Surgical algorithm for alveolar bone augmentation in implant dentistry. *Oral Maxillofac Surg Clin North Am*. 2019;31(2):155–161. doi:10.1016/j.coms.2019.01.001
5. Guarnieri R, Reda R, Di Nardo D, Miccoli G, Zanza A, Testarelli L. In vitro direct and indirect cytotoxicity comparative analysis of one pre-hydrated versus one dried acellular porcine dermal matrix. *Materials (Basel)*. 2022;15(5):1937. doi:10.3390/ma15051937
6. Guarnieri R, Reda R, Zanza A, Miccoli G, Nardo DD, Testarelli L. Can peri-implant marginal bone loss progression and a-MMP-8 be considered indicators of the subsequent onset of peri-implantitis? A 5-year study. *Diagnostics (Basel)*. 2022;12(11):2599. doi:10.3390/diagnostics12112599
7. Stahl A, Yang YP. Regenerative approaches for the treatment of large bone defects. *Tissue Eng Part B Rev*. 2021;27(6):539–547. doi:10.1089/ten.TEB.2020.0281
8. Lee J, Park D, Koo KT, Seol YJ, Lee YM. Validity of a regenerative procedure for a minor bone defect with immediate implant placement: A systematic review and meta-analysis. *Acta Odontol Scand*. 2019;77(2):99–106. doi:10.1080/00016357.2018.1508743
9. Tomas M, Čandrlić M, Juzbašić M, et al. Synthetic injectable biomaterials for alveolar bone regeneration in animal and human studies. *Materials (Basel)*. 2021;14(11):2858. doi:10.3390/ma14112858
10. Dominiak M, Dominiak S, Targonska S, Gedrange T. Three-dimensional bone block planning for mandibular sagittal bone defect reconstruction. *J Healthc Eng*. 2020;2020:8829288. doi:10.1155/2020/8829288
11. Dominiak M, Hnitecka S, Olchowy C, Dominiak S, Gedrange T. Possible treatment of severe bone dehiscences based on 3D bone reconstruction – A description of treatment methodology. *Appl Sci*. 2021;11(21):10299. doi:10.3390/app112110299
12. Baljoon M, Natto S, Bergstrom J. Occurrence of vertical bone defects in dentally aware individuals. *Acta Odontol Scand*. 2003;61(1):47–51. doi:10.1080/ode.61.1.47.51
13. El-Sioufi I, Oikonomou I, Koletsi D, Bobetsis YA, Madianos PN, Vassilopoulos S. Clinical evaluation of different alveolar ridge preservation techniques after tooth extraction: A randomized clinical trial. *Clin Oral Investig*. 2023;27(8):4471–4480. doi:10.1007/s00784-023-05068-1
14. Chinnasami H, Dey MK, Devireddy R. Three-dimensional scaffolds for bone tissue engineering. *Bioengineering (Basel)*. 2023;10(7):759. doi:10.3390/bioengineering10070759
15. Kurtiş B, Şahin S, Gürbüz S, et al. Vertical bone augmentation with customized CAD/CAM titanium mesh for severe alveolar ridge defect in the posterior mandible: A case letter. *J Oral Implantol*. 2023;49(2):147–156. doi:10.1563/aaid-joi-D-22-00094
16. Yazdanpanah Z, Johnston JD, Cooper DML, Chen X. 3D bioprinted scaffolds for bone tissue engineering: State-of-the-art and emerging technologies. *Front Bioeng Biotechnol*. 2022;10:824156. doi:10.3389/fbioe.2022.824156
17. Khoury F, Hanser T. Mandibular bone block harvesting from the retromolar region: A 10-year prospective clinical study. *Int J Oral Maxillofac Implants*. 2015;30(3):688–697. doi:10.11607/jomi.4117

18. Jacotti M, Wang HL, Fu JH, Zamboni G, Bernardello F. Ridge augmentation with mineralized block allografts: Clinical and histological evaluation of 8 cases treated with the 3-dimensional block technique. *Implant Dent*. 2012;21(6):444–448. doi:10.1097/ID.0b013e31826f7a67
19. Dorosz N, Dominiak M. Mandibular ridge reconstruction: A review of contemporary methods. *Adv Clin Exp Med*. 2018;27(8):1159–1168. doi:10.17219/acem/74054
20. Targonska S, Dominiak S, Wiglusz RJ, Dominiak M. Investigation of different types of micro- and nanostructured materials for bone grafting application. *Nanomaterials (Basel)*. 2022;12(21):3752. doi:10.3390/nano12213752
21. Page MJ, McKenzie JE, Bossuyt PM, et al. The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. *BMJ*. 2021;372:n71. doi:10.1136/bmj.n71
22. Amir-Behghadami M, Janati A. Population, Intervention, Comparison, Outcomes and Study (PICOS) design as a framework to formulate eligibility criteria in systematic reviews. *Emerg Med J*. 2020;37(6):387. doi:10.1136/emermed-2020-209567
23. Acocella A, Bertolai R, Colafranceschi M, Sacco R. Clinical, histological and histomorphometric evaluation of the healing of mandibular ramus bone block grafts for alveolar ridge augmentation before implant placement. *J Craniomaxillofac Surg*. 2010;38(3):222–230. doi:10.1016/j.jcms.2009.07.004
24. Alérico FA, Bernardes SR, Gasparini Kiatake Fontão FN, Diez GF, Alérico JHS, Claudino M. Prospective tomographic evaluation of autogenous bone resorption harvested from mandibular ramus in atrophic maxilla. *J Craniofac Surg*. 2014;25(6):e543–e546. doi:10.1097/SCS.0000000000001045
25. Anitua E, Murias-Freijo A, Alkhraisat MH. Implant site under-preparation to compensate the remodeling of an autologous bone block graft. *J Craniofac Surg*. 2015;26(5):e374–e377. doi:10.1097/SCS.0000000000001839
26. Barone A, Toti P, Menchini-Fabris GB, Felice P, Marchionni S, Covani U. Early volumetric changes after vertical augmentation of the atrophic posterior mandible with interpositional block graft versus onlay bone graft: A retrospective radiological study. *J Craniomaxillofac Surg*. 2017;45(9):1438–1447. doi:10.1016/j.jcms.2017.01.018
27. Chiapasco M, Abati S, Romeo E, Vogel G. Clinical outcome of autogenous bone blocks or guided bone regeneration with e-PTFE membranes for the reconstruction of narrow edentulous ridges. *Clin Oral Implants Res*. 1999;10(4):278–288. doi:10.1034/j.1600-0501.1999.100404.x
28. Chiapasco M, Tommasato G, Palombo D, Scarnò D, Zaniboni M, Del Fabbro M. Dental implants placed in severely atrophic jaws reconstructed with autogenous calvarium, bovine bone mineral, and collagen membranes: A 3- to 19-year retrospective follow-up study. *Clin Oral Implants Res*. 2018;29(7):725–740. doi:10.1111/clr.13281
29. De Stavola L, Tunkel J. Results of vertical bone augmentation with autogenous bone block grafts and the tunnel technique: A clinical prospective study of 10 consecutively treated patients. *Int J Periodontics Restorative Dent*. 2013;33(5):651–659. doi:10.11607/prd.0932
30. Elhadidi M, Aldahouk A, Shawky M, Elbehairy MS, Atef M, El-Gengehi M. Computer-guided calvarial mono-cortical bone blocks harvest: A novel approach for three-dimensional alveolar reconstruction of atrophic maxilla. *Clin Implant Dent Relat Res*. 2019;21(1):85–93. doi:10.1111/cid.12714
31. Felice P, Soardi E, Pellegrino G, et al. Treatment of the atrophic edentulous maxilla: Short implants versus bone augmentation for placing longer implants. Five-month post-loading results of a pilot randomised controlled trial. *Eur J Oral Implantol*. 2011;4(3):191–202. PMID:22043464.
32. Hallman M, Mordenfeld A, Strandkvist T. A retrospective 5-year follow-up study of two different titanium implant surfaces used after interpositional bone grafting for reconstruction of the atrophic edentulous maxilla. *Clin Implant Dent Relat Res*. 2005;7(3):121–126. doi:10.1111/j.1708-8208.2005.tb00055.x
33. Pistilli R, Felice P, Piatelli M, Nisii A, Barausse C, Esposito M. Blocks of autogenous bone versus xenografts for the rehabilitation of atrophic jaws with dental implants: Preliminary data from a pilot randomised controlled trial. *Eur J Oral Implantol*. 2014;7(2):153–171. PMID:24977250.
34. Qiu L, Yu H. Onlay grafting with bovine bone mineral block for horizontal reconstruction of severely atrophic alveolar ridges in anterior maxillae: A 6-year prospective study. *J Craniomaxillofac Surg*. 2018;46(8):1199–1204. doi:10.1016/j.jcms.2018.04.004
35. Rasmusson L, Thor A, Sennerby L. Stability evaluation of implants integrated in grafted and nongrafted maxillary bone: A clinical study from implant placement to abutment connection. *Clin Implant Dent Relat Res*. 2012;14(1):61–66. doi:10.1111/j.1708-8208.2010.00239.x
36. Schwartz-Arad D, Levin L. Intraoral autogenous block onlay bone grafting for extensive reconstruction of atrophic maxillary alveolar ridges. *J Periodontol*. 2005;76(4):636–641. doi:10.1902/jop.2005.76.4.636
37. Yu H, Chen L, Zhu Y, Qiu L. Bilamina cortical tenting grafting technique for three-dimensional reconstruction of severely atrophic alveolar ridges in anterior maxillae: A 6-year prospective study. *J Craniomaxillofac Surg*. 2016;44(7):868–875. doi:10.1016/j.jcms.2016.04.018
38. Zerbo IR, de Lange GL, Joldersma M, Bronckers ALJJ, Burger EH. Fate of monocortical bone blocks grafted in the human maxilla: A histological and histomorphometric study. *Clin Oral Implants Res*. 2003;14(6):759–766. doi:10.1046/j.0905-7161.2003.00967.x
39. Chaushu G, Mardinger O, Peleg M, Ghelfan O, Nissan J. Analysis of complications following augmentation with cancellous block allografts. *J Periodontol*. 2010;81(12):1759–1764. doi:10.1902/jop.2010.100235
40. Deluiz D, Santos Oliveira L, Ramôa Pires F, et al. Incorporation and remodeling of bone block allografts in the maxillary reconstruction: A randomized clinical trial. *Clin Implant Dent Relat Res*. 2017;19(1):180–194. doi:10.1111/cid.12441
41. Pereira E, Messias A, Dias R, Judas F, Salvoni A, Guerra F. Horizontal resorption of fresh-frozen corticocancellous bone blocks in the reconstruction of the atrophic maxilla at 5 months. *Clin Implant Dent Relat Res*. 2015;17 Suppl 2(Suppl 2):e444–e458. doi:10.1111/cid.12268
42. Pistilli R, Felice P, Piattelli M, et al. Posterior atrophic jaws rehabilitated with prostheses supported by 5 × 5 mm implants with a novel nanostructured calcium-incorporated titanium surface or by longer implants in augmented bone. One-year results from a randomised controlled trial. *Eur J Oral Implantol*. 2013;6(4):343–357. PMID:24570980.
43. Reininger D, Cobo-Vázquez C, Rosenberg B, López-Quiles J. Alternative intraoral donor sites to the chin and mandibular body-ramus. *J Clin Exp Dent*. 2017;9(12):e1474–e1481. doi:10.4317/jced.54372
44. Kim YK, Ku JK. Ridge augmentation in implant dentistry. *J Korean Assoc Oral Maxillofac Surg*. 2020;46(3):211–217. doi:10.5125/jkaoms.2020.46.3.211
45. Gareb B, Roossien CC, van Bakelen NB, et al. Comparison of the mechanical properties of biodegradable and titanium osteosynthesis systems used in oral and maxillofacial surgery. *Sci Rep*. 2020;10(1):18143. doi:10.1038/s41598-020-75299-9
46. Mertens C, Decker C, Seeberger R, Hoffmann J, Sander A, Freier K. Early bone resorption after vertical bone augmentation – A comparison of calvarial and iliac grafts. *Clin Oral Implants Res*. 2013;24(7):820–825. doi:10.1111/j.1600-0501.2012.02463.x
47. Sanz-Sánchez I, Sanz-Martín I, Ortiz-Vigón A, Molina A, Sanz M. Complications in bone-grafting procedures: Classification and management. *Periodontol 2000*. 2022;88(1):86–102. doi:10.1111/prd.12413
48. Friberg B. Bone augmentation for single tooth implants: A review of the literature. *Eur J Oral Implantol*. 2016;9 Suppl 1:S123–S134. PMID:27314117.
49. Schaaf H, Lendeckel S, Howaldt HP, Streckbein P. Donor site morbidity after bone harvesting from the anterior iliac crest. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod*. 2010;109(1):52–58. doi:10.1016/j.tripleo.2009.08.023
50. Dinçel YM. Bone Graft Types. In: Kummoona R, ed. *Bone Grafting – Recent Advances with Special References to Cranio-Maxillofacial Surgery*. Rijeka, Croatia: IntechOpen; 2018. doi:10.5772/intechopen.79449
51. Solakoglu Ö, Götz W, Heydecke G, Schwarzenbach H. Histological and immunohistochemical comparison of two different allogeneic bone grafting materials for alveolar ridge reconstruction: A prospective randomized trial in humans. *Clin Implant Dent Relat Res*. 2019;21(5):1002–1016. doi:10.1111/cid.12824

52. Kouhestani F, Rad MR, Mohaghegh S, Motamedian SR. Effect of metformin on the behavior of dental pulp stem cells cultured on freeze-dried bone allografts. *Dent Med Probl*. 2021;58(3):343–349. doi:10.17219/dmp/131988
53. Schmitt CM, Doering H, Schmidt T, Lutz R, Neukam FW, Schlegel KA. Histological results after maxillary sinus augmentation with Straumann® BoneCeramic, Bio-Oss®, Puros®, and autologous bone. A randomized controlled clinical trial. *Clin Oral Implants Res*. 2013;24(5):576–585. doi:10.1111/j.1600-0501.2012.02431.x
54. Araújo MG, Sonohara M, Hayacibara R, Cardaropoli G, Lindhe J. Lateral ridge augmentation by the use of grafts comprised of autologous bone or a biomaterial. An experiment in the dog. *J Clin Periodontol*. 2002;29(12):1122–1131. doi:10.1034/j.1600-051x.2002.291213.x
55. Ortiz-Vigón A, Suarez I, Martínez-Villa S, Sanz-Martín I, Bollain J, Sanz M. Safety and performance of a novel collagenated xenogeneic bone block for lateral alveolar crest augmentation for staged implant placement. *Clin Oral Implants Res*. 2018;29(1):36–45. doi:10.1111/clr.13036
56. Xuan F, Lee CU, Son JS, Fang Y, Jeong SM, Choi BH. Vertical ridge augmentation using xenogenous bone blocks: A comparison between the flap and tunneling procedures. *J Oral Maxillofac Surg*. 2014;72(9):1660–1670. doi:10.1016/j.joms.2014.04.003
57. Stübinger S, Nuss K, Landes C, von Rechenberg B, Sader R. Harvesting of intraoral autogenous block grafts from the chin and ramus region: Preliminary results with a variable square pulse Er:YAG laser. *Lasers Surg Med*. 2008;40(5):312–318. doi:10.1002/lsm.20639
58. Starch-Jensen T, Deluiz D, Deb S, Bruun NH, Tinoco EMB. Harvesting of autogenous bone graft from the ascending mandibular ramus compared with the chin region: A systematic review and meta-analysis focusing on complications and donor site morbidity. *J Oral Maxillofac Res*. 2020;11(3):e1. doi:10.5037/jomr.2020.11301
59. Nilius M, Nilius MH, Mueller C, et al. Customized allogeneic bone augmentation improves esthetic outcome in anteromaxillary dental implantation. *Case Rep Dent*. 2022;2022:6943930. doi:10.1155/2022/6943930
60. Egierska D, Perszke M, Mazur M, Duś-Ilnicka I. Platelet-rich plasma and platelet-rich fibrin in oral surgery: A narrative review. *Dent Med Probl*. 2023;60(1):177–186. doi:10.17219/dmp/147298
61. Ritto FG, Pimentel T, Canellas JVS, Junger B, Cruz M, Medeiros PJ. Randomized double-blind clinical trial evaluation of bone healing after third molar surgery with the use of leukocyte- and platelet-rich fibrin. *Int J Oral Maxillofac Surg*. 2019;48(8):1088–1093. doi:10.1016/j.ijom.2019.01.020
62. Simonpieri A, Del Corso M, Vervelle A, et al. Current knowledge and perspectives for the use of platelet-rich plasma (PRP) and platelet-rich fibrin (PRF) in oral and maxillofacial surgery part 2: Bone graft, implant and reconstructive surgery. *Curr Pharm Biotechnol*. 2012;13(7):1231–1256. doi:10.2174/138920112800624472
63. Bhattacharya HS, Gummaluri SS, Rani A, Verma S, Bhattacharya P, Rayashettypura Gurushanth SM. Additional benefits of titanium platelet-rich fibrin (T-PRF) with a coronally advanced flap (CAF) for recession coverage: A case series. *Dent Med Probl*. 2023;60(2):279–285. doi:10.17219/dmp/141919

8.3. Publikacja 3: Possible Treatment of Severe Bone Dehiscences Based on 3D Bone Reconstruction- A Description of Treatment Methodology.

applied sciences

MDPI

Case Report

Possible Treatment of Severe Bone Dehiscences Based on 3D Bone Reconstruction—A Description of Treatment Methodology

Marzena Dominiak [1], Sylwia Hnitecka [2,*], Cyprian Olchowy [1], Sebastian Dominiak [1] and Tomasz Gedrange [3]

1 Department of Oral Surgery, Wroclaw Medical University, Krakowska 26, 50-425 Wrocław, Poland; marzena.dominiak@umed.wroc.pl (M.D.); cyprian.olchowy@umed.wroc.pl (C.O.); sebastian.dominiak@umed.wroc.pl (S.D.)
2 Department of Maxillofacial Surgery, Wroclaw Medical University, Borowska 231, 50-556 Wrocław, Poland
3 Division of Orthodontics, Technische Universität Dresden, 01062 Dresden, Germany; tomasz.gedrange@umed.wroc.pl
* Correspondence: sylwia.hnitecka@umed.wroc.pl

Abstract: Gingival recessions constitute serious limitations for effective interdisciplinary periodontal, orthodontic, and implant therapy. A proper bone morphology of the alveolar bone and soft tissues that cover it are interdependent. The regeneration procedures known to date are based on the use of autogenous bone, or its allogeneic, xenogeneic, or alloplastic substitutes. These substitutes are characterized by different osteogenesis potentials. No effective procedure for three-dimensional bone reconstruction for cases in which there is dentition with recessions has been described to date, especially in its vertical dimension. This article presents the patented method of the three-dimensional bone reconstruction of the anterior mandible with preserved dentition when using an allogeneic bone block, and also includes a case report with a 2-year follow-up as an example. Based on clinical observations, it was stated that the intended therapeutic effect was achieved. There was no recession, shallowing of the vestibule, signs of inflammation, or pathological mobility of the teeth in the area undergoing reconstruction. The radiographic images revealed the formation of a new layer of cortical bone on the vestibular side and a certain volume of cancellous bone. No radiological demarcation zone of brightening, which indicates an incomplete adaptation, integration, and reconstruction of the bone block, was found.

Keywords: allogeneic bone; bone block; bone reconstruction; dehiscences; gingival recessions; mandibular reconstruction

check for updates

Citation: Dominiak, M.; Hnitecka, S.; Olchowy, C.; Dominiak, S.; Gedrange, T. Possible Treatment of Severe Bone Dehiscences Based on 3D Bone Reconstruction—A Description of Treatment Methodology. *Appl. Sci.* **2021**, *11*, 10299. https://doi.org/10.3390/app112110299

Academic Editors: Morena Petrini, Stefano Gennai and Dorina Lauritano

Received: 4 September 2021
Accepted: 29 October 2021
Published: 2 November 2021

1. Introduction

Gingival recessions are not only a significant problem of an aesthetic nature, but also constitute serious limitations for effective interdisciplinary periodontal, orthodontic and implant therapy—especially when they are accompanied by an advanced loss of bone [1,2].

Correct bone morphology of the alveolar bone, as well as the soft tissues that cover it (periosteum and gingiva), are interdependent [3]. Khoury et al. highlight the important role of a three-dimensional stable base with periosteum, which is the source of signaling factors for physiological remodeling. A lack of cancellous bone, considered as the primary developmental condition in some patients, or the effect of its pathological loss, results in a thin layer of compact bone in a given area. In such a case, due to the lack of a three-dimensional stable base, there is a consistent loss of bone—even when the periosteum is preserved [3].

In these cases, there is only an avascular base created by exposed surfaces of tooth roots for potential regeneration. This is an unpredictable therapeutic challenge in terms of restoring the correct morphology of a given area [4]. In turn, the abandonment of reconstruction leads to the loss of the support of teeth, their loosening, and as a result their loss. At the same time, there is also a lack of adequate dimensions of the avascular base to conduct the subsequent implantation [5].

The regeneration procedures known to date are based on the use of autogenous bone, or its allogeneic, xenogeneic, or alloplastic substitutes, which exhibit different osteogenesis potentials. Biomaterials are available in the form of blocks or crushed chips and granules [6,7]. Autogenous grafts provide optimal osteoconductive, osteoinductive, and osteogenic properties. However, donor site morbidity, costs, and the fact that stable blocks of autogenous bone are not always sufficient for regenerating an existing defect prompt one to look for alternative biomaterials. Alloplastic and xenogenous materials are mainly osteoconductive without the intrinsic potential for osteogenesis or osteoinduction. Although they are readily available commercially, they do not constitute a "gold standard". Therefore, an ideal compromise seems to be an allogenic material that exerts both an osteoconductive and osteoinductive potential [7–9].

Therefore, in regenerative surgery, the use of techniques aimed to obtain three-dimensional structures of porous scaffolds is gaining increased popularity [10,11]. The use of volumetric tomography scans of bone defects allows for designing and creating a bone block that fits the recipient's site and adheres to it with its entire surface. It is desirable that not only the macrostructure of the scaffold fits the defect, but also that this microstructure should favor angiogenesis, cell migration, and the diffusion of nutrients. This so-called biomimetism then leads to regeneration within the graft through the adhesion, proliferation, and differentiation of cells [11].

Modern methods enable to obtain an adequate volume of bone tissue within the edentulous alveolar bone. They are described in the literature with reports of their high effectiveness during long-term observation [12–14].

However, no effective procedure for three-dimensional bone reconstruction for cases in which there is dentition with recessions has been described to date, especially with regards to the bone's vertical dimension.

The aim of this case report was to describe the patented method of the three-dimensional bone reconstruction of the anterior mandible with preserved dentition when using an allogeneic bone block. The additional goal was to report the results of the method presenting a case with a 2-year follow-up as an example.

2. Materials and Methods

The reconstruction method is presented based on a case description of a 21-year-old, generally healthy patient who was referred to a dental clinic due to pathological mobility of his front teeth in the mandible. The patient had started orthodontic treatment with fixed appliances three months earlier. The patient has never undergone any surgical or periodontal treatment in a given area of the mandible. He also denied facial injuries.

A clinical examination revealed an inadequate amount of keratinized gingiva, Miller grade II gingival recession in the area of tooth 42 (right lateral incisor in the mandible), a thin biotype of the gingiva with the correct vestibule height, as well as marked alveolar concaves and convexities [Figure 1]. Probing depth (PD) was 1–2 mm around lower incisors and canines. Bleeding on probing (BoP) was found in incisors. Attention was also paid to insufficient oral hygiene and plaque and calculus deposits. The patient underwent scaling and root planning. It was also recommended to perform cone-beam computed tomography (CBCT) of the anterior mandible. CBCT scans were captured using Pax Flex3D Vatech Computer Tomography X-ray System (Vatech, Hwaseong-si, Gyeonggi-do, Korea) with FOV 80 mm width and 50 mm height. Images were analyzed using EzDent-i software (Vatech, Hwaseong-si, Gyeonggi-do, Korea).

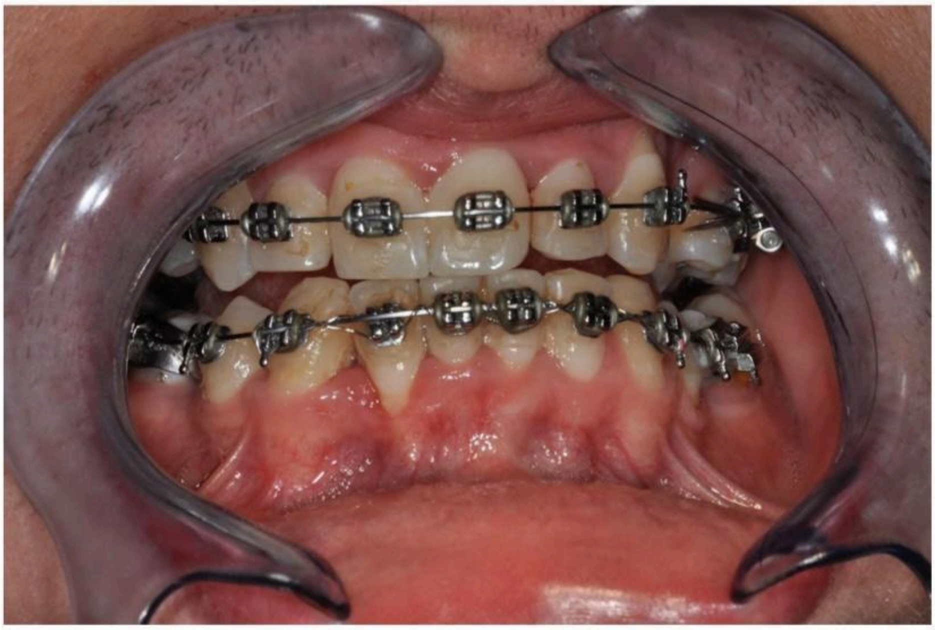


Figure 1. Clinical picture before treatment showing the inadequate amount of keratinized gingiva, Miller grade II gingival recession in the area of tooth 42, a thin biotype of the gingiva with the correct vestibule height as well as including calculus, gingival recessions, and alveolar concaves and concavities.

A radiological examination revealed a significant bone deficiency in this area, with clearly marked concavities in the alveolar part of the mandible. Advanced bone dehiscences from the vestibular side, with almost complete exposure of the anterior tooth roots, were also seen [Figures 2–4].

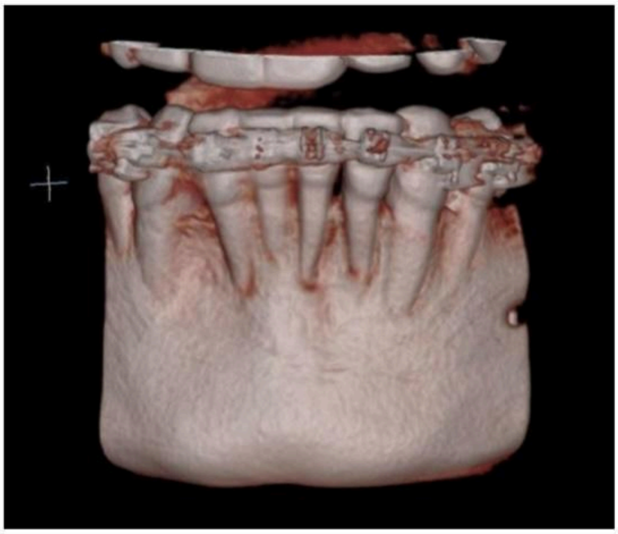


Figure 2. CBCT image before the treatment showing advanced bone defects—three-dimensional reconstruction.

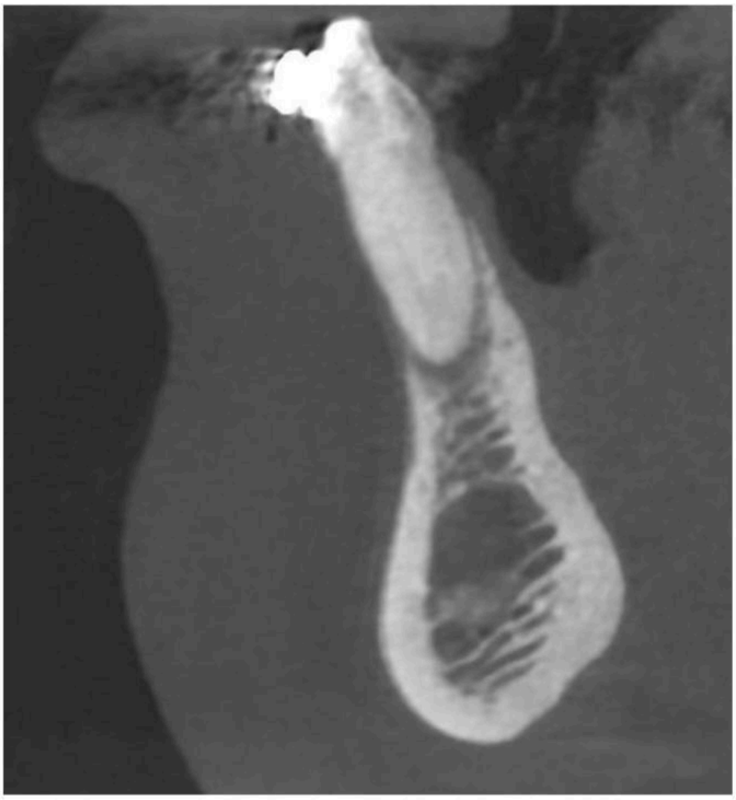


Figure 3. CBCT image before the treatment showing an almost complete loss of the buccal bone—sagittal section.

The morphology of this region could be classified as C according to the alveolar bone dehiscence classification proposed by Yang et al. [15]. This means that the dehiscence is bilateral. In turn, according to the modification of this classification presented by Dominiak et al., which is more detailed, such a defect could be classified as BDIEII dehiscence from the vestibular side, which reaches an apical foramen, and bone loss from the lingual side is at the level of 1/2 of the root's length [16].

Due to the inadequate dimensions and volume of soft tissues, as well as the consistent lack of the possibility of adequate bone reconstruction without excessive tension, it was decided to start with gingival augmentation—connective tissue graft (CTG). Tissue grafts are an indispensable stage in the reconstruction of the mucogingival complex.

Under local anesthesia with a 4% solution of articaine with epinephrine 1:100,000 (Ubistesin forte, 3M™ eSPe™, Wroclaw, Poland) the receiving bed in area 32–42 was prepared. A CTG was obtained from the palate and was then sutured into the recipient site. Excessive activity of the mental muscle, which causes the pull of soft tissues, was eliminated by intramuscular injection of botulinum toxin (0.6 mL in the horizontal line; usually, about 24 IU is required (BOTOX® Cosmetic, Allergan, Dublin, Ireland) [17,18].

In the clinical follow-up examination, which was conducted after less than three months, the adequate width and thickness of the soft tissues, as well as the complete coverage of the recession in the area of tooth 42 were recorded. It was therefore decided to start bone reconstruction surgery.

Figure 4. CBCT image before the treatment—axial section.

The bone reconstruction procedure with the use of an individualized three-dimensional allogeneic bone block was carried out according to the method patented by Dominiak and Gedrange (EP3287097B1, 2016). First, the block was positioned in relation to skeletal and facial parameters. An orthodontic diagnostic, including CBCT scans, intraoral and extraoral face scans, and a valid lateral cephalogram, was conducted.

In the second stage, the positioning of the block was based on the height, width and thickness of the alveolar bone, as well as the shape of the internal surface of the block. In addition, muscle and soft tissue parameters were evaluated, especially the thickness of the mental muscle (clinically known as the "orange peel" sign). Radiological diagnosis was also conducted, including a cephalometric radiograph, CBCT scans, and elastographic imaging.

The area of the defect was divided into 4 external regions and 1 internal region, and reference points were marked on the recipient field. A personalized bone block has to be highly suitable, thus the internal surface of the block was then assessed to adjust the contact area with the underlying bone to be as wide as possible.

The cephalometric analysis included the measurement of the ANB angle and the definition of the facial type. The correlation between the incisor position and the mandible and the inclination of the mandibular incisors was evaluated. Moreover, the relationship between the upper and lower incisors was considered.

It was extremely important to determine the alveolar bone level. For the prediction of bone resorption with regards to tooth movement, the ALi- CEJ2-B angle was evaluated. For this purpose, three points were set: the deepest concavity on the anterior surface of the mandibular symphysis (point B), the apical point of the most anterior mandibular central incisor (Iia), and the point on the cementoenamel junction of the incisor (CEJ) minus 2 mm, which corresponds to the sulcus depth. CBCT scans were used for shape planning of the whole bone block.

The target values were updated to include the actual reference point values, and a new area with target values was added to the diagnostic defect area. The bone block body was connected with the first analyzed plane of the mandibular segments with the applied bone block. The ANB angle was taken into consideration to ensure face harmony after reconstruction. The shape of the chin and the block's design were also adjusted. It was important to keep the block thickness within the thickness of the possible physiological bone regeneration. According to the method, the value of the ANB angle should not exceed 4–5° after reconstruction. Moreover, the long axis of the basal symphysis and the alveolar symphysis should be positioned as parallel to each other as possible, and the overall angle created between them should not exceed 10°. The chin's form and the block's design were also tweaked. It was critical that the thickness of the block did not surpass the thickness of feasible physiological bone regeneration. After reconstruction, the ANB angle should not exceed 4–5 degrees, according to the procedure. Furthermore, the long axis of the basal symphysis and the alveolar symphysis should be as parallel to each other as feasible, with an overall angle of no more than 10° between them. The shape and the position of the basal symphysis cannot be influenced by the tooth movement of the lower incisors.

The width of the bone block depended on the size of the bone defect. The assessment was carried out by the surgeon based on the analysis of the horizontal cross-section of the alveolar process, as well as objectively with the use of orthodontic analysis. The width was assessed from the right to the left canine to ensure it always matches the shape of the mandible in all dimensions. The incisor crowns were measured, and the measured value determined the arch shape between the canines. The position of the teeth and the alveolar process were drawn on CBCT scans and supplemented with the perfect size of the arch.

The height of the bone block was assessed using two measurements: in the direction of the crown and the apex, while the level of the crestal bone was positioned at the CEJ level minus 2–3 mm which is the biological width of teeth with healthy periodontium. The gingival biotype evaluation was performed using the puncture technique, which was followed by reading the values from the periodontal probe scale.

Then came the phase of computer-aided design and manufacturing (CAD/CAM). A virtual model of the mandible was created by converting CBCT scans and intraoral scans into digital models. A bone block design was placed on the model, and the actual and target value points were placed into one unit. A suitable live donor was selected according to predetermined aspects: an adequate amount of cancellous and/or cortical bone (in this case only cancellous bone), proper bone density-D2-D3 according to Misch. After milling, the block was cleaned, packed, sterilized, and sent to the surgeon. A detailed description of bone block planning, including diagrams of the procedure, has been previously described [16].

The bone reconstruction was performed under local anesthesia with a 4% solution of articaine and epinephrine 1: 100,000 (Ubistesin forte, 3M™ eSPe™, Wroclaw, Poland), and also with an antibiotic—0.6 g of clindamycin administered p.o. 1 h before the procedure (Clindamycin MIP, MIP Pharma GmbH, Blieskastel, Germany). The entire surgical procedure was carried out following a previously established scheme. Photos of the key moments of the surgery show the procedure of another patient who had the same operation. The only difference is the type of bone block fixation. In the presented case, resorbable pins made of amorphous poly-(d,l)-lactide were used, while the photos show a procedure that uses titanium screws. Both variants are acceptable and effective for fixing the block. When titanium screws are used, they are gently removed after 6–8 weeks.

First, an intrasulcular incision was made two spaces mesially and distally wider than the planned treatment area and the envelope mucoperiosteal flap was elevated beyond the mental eminence to create a receiving bed without an excessive tension of the flap. Due to this, bone dehiscences and concavities of the mandibular alveolar part were exposed [Figure 5].

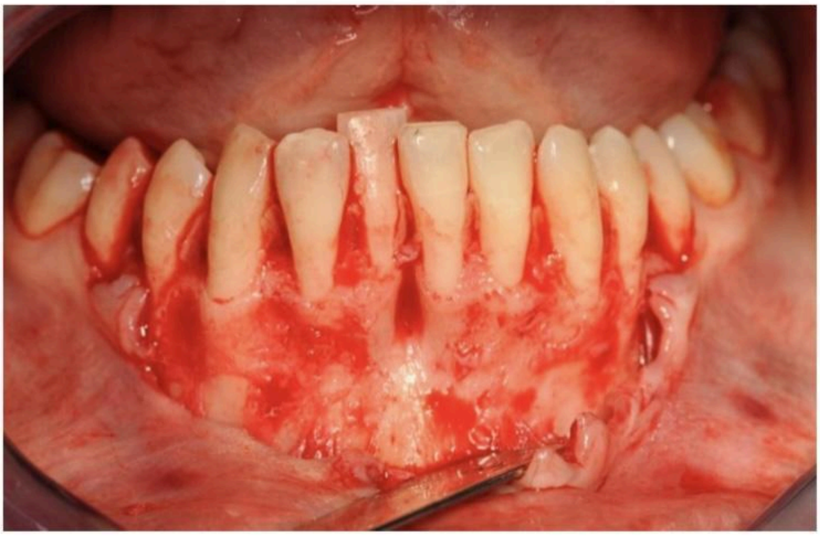


Figure 5. Exposed tooth roots and bone dehiscences. Picture taken after mucoperiosteal flap elevation in the area of planned bone reconstruction.

Root surfaces were then mechanically cleaned of deposits, without the use of additional substances. Afterward, a drill was used to decorticate the cortical layer in the interdental spaces to improve vascularization, and advanced platelet-rich fibrin (A-PRF) membranes were prepared from then peripheral patient's blood and placed on its surface (PRF Duo, Process for PRF, Nice, France) [19]. Allogeneic bone particles obtained from the Bone Bank in Poland were introduced into the deepest bone defects, followed by the placement of an individualized three-dimensional block of allogeneic bone [Figure 6].

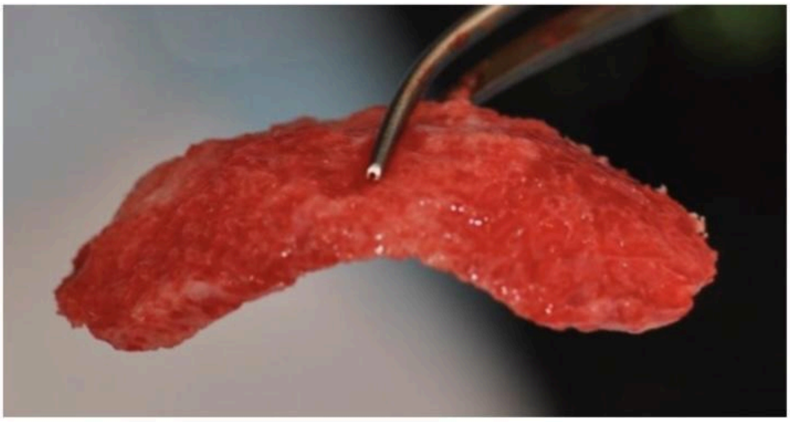


Figure 6. Individualized allogeneic bone block soaked in injectable platelet-rich fibrin before placement.

In order to immobilize the bone block, and for its appropriate adaptation to the base, two 11 mm long resorbable polylactaic pins were ultrasonically introduced using the SonicWeld Rx® technique (KLS Martin, Jacksonville, FL, USA). Titanium screws can be used instead of resorbable pins, but should be removed after 6–8 weeks. Screws of about 8 mm long are usually used, i.e., Surgident Co (Daegu, Korea) [Figure 7].

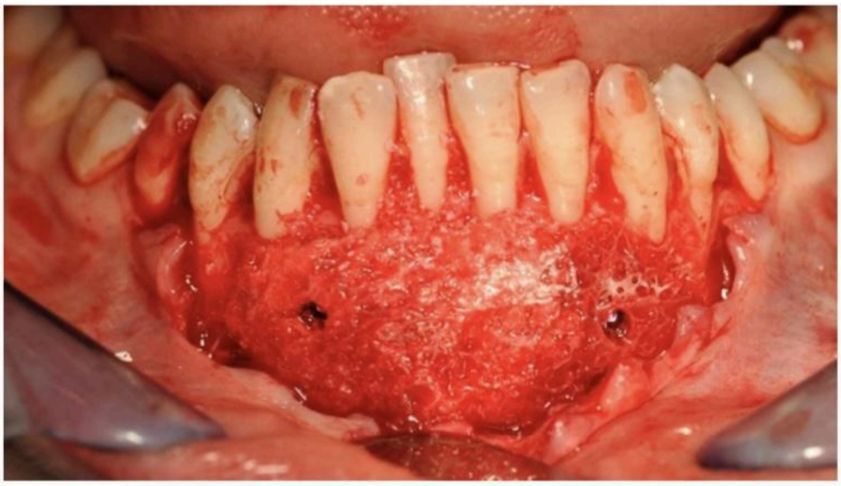


Figure 7. Bone block fixed to the mandibular bone—a recipient site with titanium screws.

The A-PRF membranes were placed on the outer surface [Figure 8], and a resorbable collagen barrier membrane Geistlich Bio-Gide (Geistlich Pharma AG, Wolhusen, Switzerland), which was previously soaked in a liquid fraction of injectable platelet-rich fibrin (i-PRF) (PRF Duo, Process for PRF, Nice, France) was placed apically.

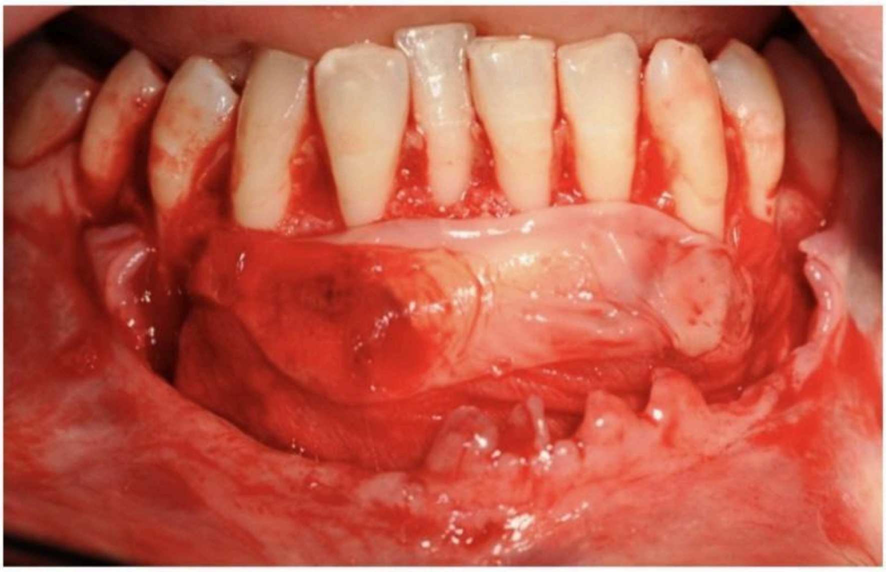


Figure 8. Advanced platelet-rich fibrin and collagen membranes placed on the surface of the bone block.

The selected barrier membrane consists of pure non-cross-linked collagen. Its purpose is to prevent the penetration of connective tissue under the block in the chin. It cannot significantly alter the vascularization of the bone block, and therefore it must be of rapid resorption. The last stage involved suturing using the technique of suspended and mattress sutures, which prevented excessive tension of soft tissues (Figure 9).

Figure 9. Reposition and suturing of the soft tissue without extensive tension.

An antibiotic, 0.6 g clindamycin, twice daily and an analgesic and anti-swelling agent for three days were prescribed. The patient was instructed to maintain appropriate oral hygiene using an antiseptic foam preparation and also to use a soft post-treatment brush. Immediately after the procedure, biostimulation with the Nd: YAG laser (10 Hz, 0.5 W) was performed (TwinLight®, Fotona, Ljubljana, Slovenia). The sutures were removed two weeks after the surgery.

Written informed consent was obtained from the patient. The study was conducted according to the guidelines of the Declaration of Helsinki, and the Bioethics Committee's approval was obtained (KB-530/2021) (Bioethics Committee of Wroclaw Medical University).

3. Results

The first follow-up CBCT examination was performed after twelve months. A progressive remodeling of the bone block with its perfect adherence to the bone was visible. The correct arch curvature was also restored, and a significant increase in the volume of the bone covering the roots of the teeth was achieved. The clinical examination showed no signs of inflammation or recession at that time. Probing depth did not change significantly. There was no calculus and no bleeding on probing (Figure 10).

Another follow-up radiographic examination two years after the reconstruction procedure revealed the complete remodeling of the allogeneic material, as well as the formation of the vestibular cortical layer, despite the fact that the surgical procedure used a block that only consisted of cancellous bone. The correct morphology of the mandibular alveolar part was restored with a significant reduction in dehiscence. Clinically, there were no signs of inflammation or gingival recession, and the correct depth of the oral vestibule was maintained. The lower incisors and canines did not show excessive mobility.

Figure 10. Clinical follow-up picture showing proper occlusion, the adequate amount of keratinized gingiva, effect of gingival recession coverage with the correct vestibule height as well as lack of calculus and advanced alveolar concaves and concavities. There was only a slight reddening of the gingiva in area 42 associated with a small loose bone fragment resulting from the remodeling of the graft.

In order to assess the scope of the reconstruction, radiological measurements of the width of the mandibular alveolar bone were performed in the sagittal plane both before the reconstruction procedure and after two years (Figures 11–13). Both CBCT examinations were performed using the same equipment and the same imaging parameters. Measurements were taken at certain adopted reference points within the area of tooth 31 (medial left incisor in the mandible). The reference lines were set perpendicular to each other, with one of them being along the long axis of the tooth's root.

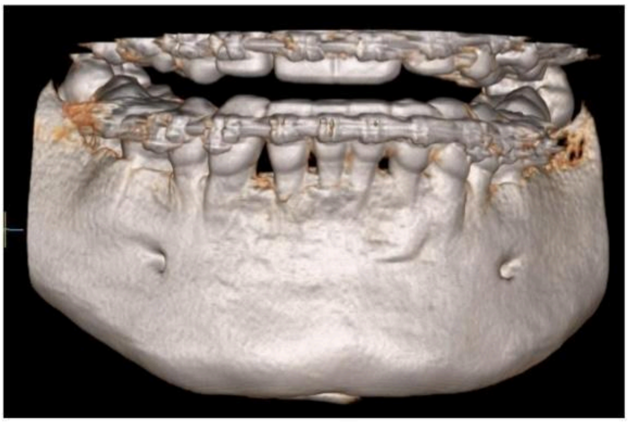


Figure 11. CBCT image two years after the surgical treatment—three-dimensional reconstruction.

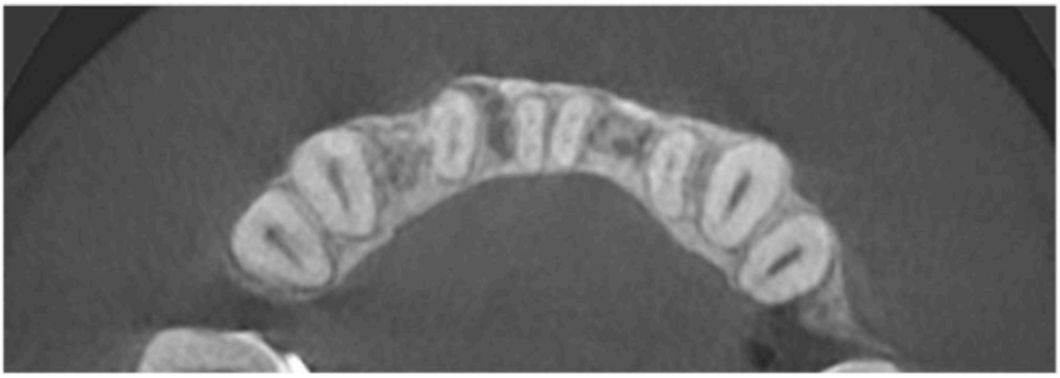


Figure 12. CBCT image two years after the surgical treatment—axial view.

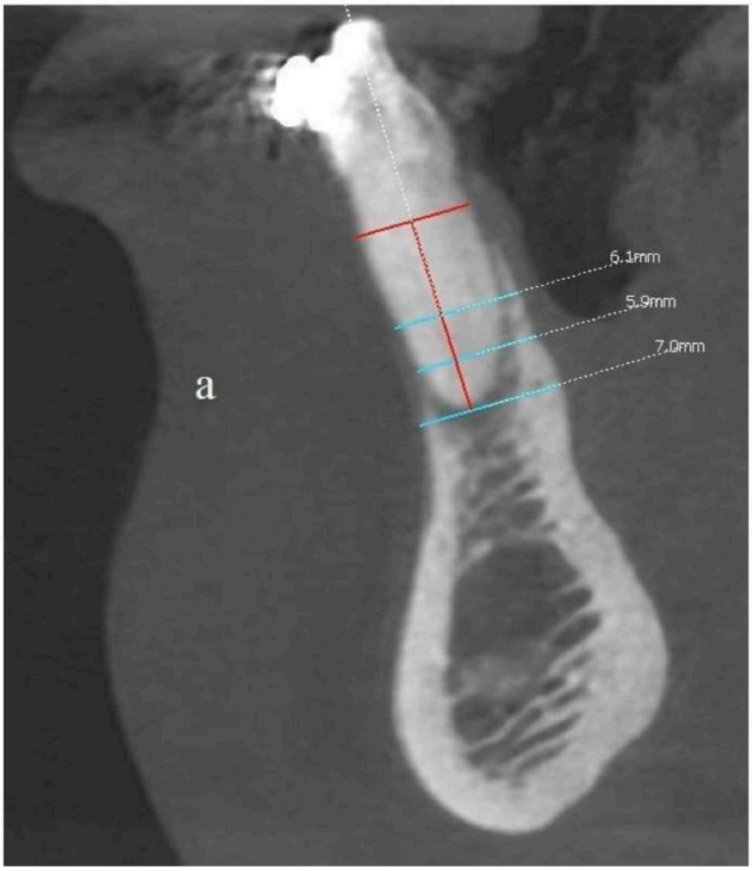


Figure 13. *Cont.*

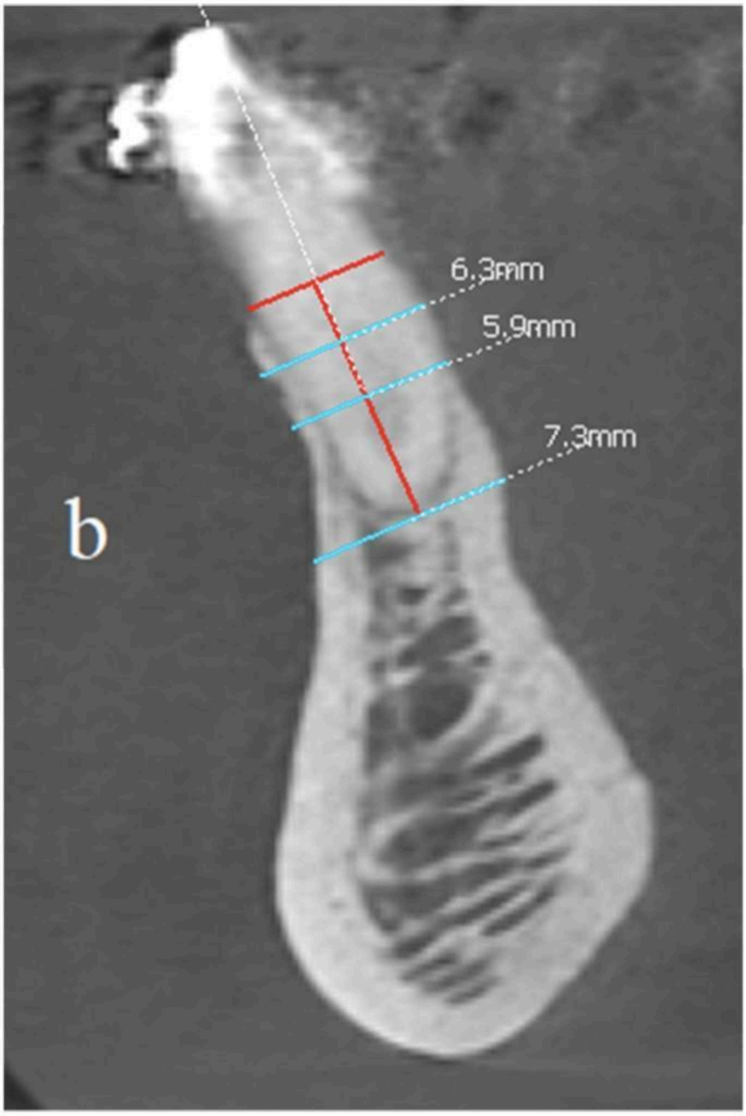


Figure 13. (**a**,**b**) Comparison of the CBCT scans (sagittal view) before the procedure and two years after the surgical treatment. Before and after images at the same location, the same threshold level is used.

The comparison of the baseline dimensions and those at the end of the follow-up were as follows:

- The bone width at the half-length from the cementoenamel junction, minus 2 mm, (CEJ-2) to the apex: 6.1 mm before surgery, 6.3 mm after surgery; difference +0.2 mm;
- The bone width at the quarter-length from the CEJ-2 to the apex: 5.9 mm before surgery, 5.9 mm after surgery; difference 0 mm;

- Bone width measured at the height of the apex: 7 mm before the procedure, 7.3 mm after the procedure; difference + 0.3 mm;
- Bone dehiscence from the vestibular side (calculated from the CEJ-2 point): 7.5 mm before the procedure, 1 mm after the procedure; difference −6.5 mm.

The final dimensions after the observation period were not only influenced by the reconstruction procedure, but also by the orthodontic movement of the teeth (Figure 13a,b).

4. Discussion

Asa'ad et al., when focusing on the topic of bone tissue engineering, emphasized the significant benefits of introducing scaffolds with a three-dimensional structure, which imitate the extracellular matrix. By design, this promotes the adhesion, proliferation, and differentiation of cells. They also mentioned that the used biomaterials must be compatible with the native environment, and consequently must lead to regeneration, not repair in which scar tissue is formed. The authors describe scaffolds combined with stem cells and/or osteoprogenitor cells, which are placed on the prefabricated scaffold or incorporated through encapsulation during the production of the scaffold. This is performed by using a hydrogel polymer matrix and by capturing the cells within a semipermeable membrane. They paid attention to the fact that the regeneration process begins peripherally in the places where biomaterials come into contact with the bone, which emphasizes the essence of the perfect adhesion of the implant to the recipient site [11].

Rasperini et al. presented a therapeutic method that aimed to regenerate periodontium using a three-dimensional resorbable polymer scaffold in the course of an aggressive form of periodontitis. Their design included the conducting of perforations to immobilize the scaffold, the internal port for the delivery of recombinant human platelet-derived growth factor-BB (rhPDGF-BB), and the protruding perpendicular elements to produce periodontal ligament. During a 12-month observation, when the scaffold was completely covered with soft tissues, the authors observed a 3 mm improvement in the connective tissue attachment, and also partial coverage of the previously exposed root. However, after 13 months, the scaffold was exposed to the oral environment. Fragments of the scaffold were removed and replaced by amelogenin, and then the pocket was sealed with surgical cyanoacrylate gel. Due to this, the graft was uncovered 3 mm below the gingival margin, which required the removal of the exposed fragment. Afterward, there was an increase in dehiscence, which resulted in the need to completely remove the scaffold. Finally, it was found after 14 months that 75.9% of the scaffold's molecular weight remained and that the healing mainly concerned the connective tissue—with minimal evidence of bone repair. Ultimately, the therapy was not proven to be successful. This procedure also required several preparatory steps, a meticulous three-dimensional design, and involved the use of polymers and a recombinant growth factor. However, the authors confirmed the correctness of using biomaterials with a three-dimensional structure, but at the same time raised doubts about the use of a polycaprolactone scaffold. The failure to achieve the desired effect was also explained by the fact that the used material was high in volume and slowly resorbing [20].

An implant material should not only be easy to use but also be perfectly biocompatible for it to be able to integrate, remodel and provide an appropriate scaffold for osteogenic cells. Allogeneic bone blocks fulfill these criteria [7,8]. However, the collection of autogenous blocks and the use of allogeneic blocks supplied from tissue banks require shaping and fitting when the traditional intra-procedure approach is used. In turn, the use of CAD/CAM technology significantly improves this process. The use of allogeneic bone is also associated with reduced surgical intervention and blood loss, a lack of donor site complications, and negligible antigenicity [21].

The success of treatments with the use of this type of biomaterial is estimated at about 90% in the literature, but an increased risk of its contamination and, consequently, of infectious complications when compared to autogenous blocks cannot be omitted. However, it has been determined that these complications either occur when matching the block to the bone defect or are the result of improper management of soft tissues, which results in the exposure of the graft, the opening of the wound, and perforation of the mucosa [22,23]. It was also shown that these complications are more common in the mandible due to its lower vascularization, as well as the fact that the flap is more difficult to manage [12]. Thus, proper evaluation of soft tissues is essential in planning bone augmentation procedures. In cases of an insufficient amount of soft tissues and an increased risk of the inability to close the wound without excessive tension of the flap, implementation of correction/augmentation procedures preceding the actual bone reconstruction surgery is recommended. Such a procedure was carried out in the presented case.

The performed procedures conducted on soft tissues allowed for obtaining their sufficient width and thickness and avoiding the primary closure of the wound with excessive tension of the flap. In turn, the use of a fully individualized three-dimensional allogeneic bone block allowed for the restoration of the correct morphology of the anterior mandibular segment of the alveolar part, which had dentition, and which was characterized with existing advanced soft tissue dehiscences and recessions. The perfect fit of the block to the recipient site minimized the risk of graft contamination when adjusting it in the shortest possible contact time, and at the same time ensuring its stability and the lack of mobility towards the base.

After two years, based on clinical observations, it was stated that the intended therapeutic effect was achieved. There was no recession, shallowing of the vestibule, signs of inflammation, or pathological mobility of the teeth in the area undergoing reconstruction. The radiographic images revealed the formation of a new layer of cortical bone on the vestibular side and a certain volume of cancellous bone. It is worth noting that the block was prepared only from the spongy bone. This is probably related to the way bone blocks are remodeled, which depends on the force and physiological loads acting on them [24]. Moreover, there was no radiological demarcation zone of brightening, which could indicate an incomplete adaptation, integration and reconstruction of the bone block.

Similar findings in CBCT studies were reported by Blume et al., who also indicated the formation of a compact bone layer after a 10-month observation. Their histological analysis confirmed that the augmented tissues showed a high degree of mineralization, without signs of inflammation. Moreover, the ongoing reconstruction process was noticed. Concavities, which are characteristic of remodeling, were also observed. They concluded that the area of nonmineralized tissue located apically to the specimen probably resulted from soft tissue parts being attached to the outer surface. Soft tissue was also observed at the apical part of the specimen. The authors concluded that the accumulation of soft tissue represents the border zone between the graft and the native bone. They also emphasized that an area with the increased lining of connective tissue at the distal part of the biopsy specimen indicates the border zone between native bone and augmented bone [22].

The limitation of this method is the cost of making the bone block, which requires many stages, both in terms of planning and production. Due to the fact that this is a patented method not yet in commercial use, it increases the costs further. However, we hope that the detailed presentation of the method, both in the technical and clinical aspects, along with showing its positive results, will allow for commercialization and widespread use in specific patients' indications. To confirm the effectiveness of the reconstruction and to show the bone remodeling, patients are subjected to CBCT scans every six months (up to 2–3 years). However, we plan to reduce the frequency and number of control radiological examinations after testing a large group of patients, proving the correct method of remodeling, and obtaining the final results. In the future, we also plan to focus on additional activities and materials that added to the described and developed method, would allow for an even better degree of reconstruction. These include, for example, growth factors, laser therapy.

5. Conclusions

In conclusion, our observation of treatments with the use of an individualized three-dimensional bone block allows us to distinguish the many advantages resulting from this method. Careful planning, considering clinical and radiological examination, as well as orthodontic and periodontal evaluation with the precise fabrication of such a bone block contributes to the providing of a three-dimensional structure that facilitates cell adhesion and angiogenesis with a low risk of complications and immune reactions. For this process, tissue banks that allow obtaining a graft are of importance. Using tailored blocks adjusted to each patient individually makes the procedure shorter and easier, without the need for intraoperative modeling of their shape and surfaces. It is possible to achieve perfect adhesion along the entire surface and to avoid micromovements. The great success of this method is the effect of the bone reconstruction in the area of the teeth in their vertical dimensions.

Author Contributions: Conceptualization, M.D. and T.G.; methodology, M.D. and T.G.; investigation, M.D., S.H., C.O. and T.G.; resources, M.D.; data curation, M.D., S.H., C.O., S.D. and T.G.; writing—original draft preparation, M.D., S.H. and C.O.; writing—review and editing, M.D., S.H., C.O. and S.D.; supervision, M.D. and T.G. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study. Written informed consent has been obtained from the patient to publish this paper.

Data Availability Statement: Authors.

Conflicts of Interest: The authors declare no conflict of interest.

Patents: T. Gedrange and M. Dominiak, "Verwendung einer Kenngröße eines Individuums zur Beurteilung des Risikos eines Zahnfleisch- und/oder Knochenschwundes an einem Schneidezahn", European Patent Office, Munich, Germany, 2016, EP3287097B1.

References

1. Dominiak, M.; Gedrange, T. New Perspectives in the Diagnostic of Gingival Recession. *Adv. Clin. Exp. Med.* **2014**, *23*, 857–863. [CrossRef] [PubMed]
2. Puzio, M.; Błaszczyszyn, A.; Hadzik, J.; Dominiak, M. Ultrasound assessment of soft tissue augmentation around implants in the aesthetic zone using a connective tissue graft and xenogeneic collagen matrix-1-year randomised follow-up. *Ann. Anat.* **2018**, *217*, 129–141. [CrossRef]
3. Khoury, F.; Hanser, T. Mandibular bone block harvesting from the retromolar region: A 10-year prospective clinical study. *Int. J. Oral Maxillofac. Implant.* **2015**, *30*, 688–697. [CrossRef]
4. Esteibar, J.R.; Zorzano, L.A.; Cundín, E.E.; Blanco, J.D.; Medina, J.R. Complete root coverage of Miller Class III recessions. *Int. J. Periodontics Restor. Dent* **2011**, *31*, e1–e7.
5. Warmuz, J.; Puszkiel, P.; Botzenhart, U.; Gedrange, T.; Dominiak, M. Practical application of a method for assessing the progression of gingival recessions in orthodontically treated patients—A pilot study. *Oral Health Dent. Manag.* **2014**, *13*, 772–778. [PubMed]
6. Khoury, F.; Hanser, T. Three-Dimensional Vertical Alveolar Ridge Augmentation in the Posterior Maxilla: A 10-year Clinical Study. *Int. J. Oral Maxillofac. Implant.* **2019**, *34*, 471–480. [CrossRef] [PubMed]
7. Sheikh, Z.; Sima, C.; Glogauer, M. Bone Replacement Materials and Techniques Used for Achieving Vertical Alveolar Bone Augmentation. *Materials* **2015**, *8*, 2953–2993. [CrossRef]
8. Dorosz, N.; Dominiak, M. Mandibular ridge reconstruction: A review of contemporary methods. *Adv. Clin. Exp. Med.* **2018**, *27*, 1159–1168. [CrossRef]
9. Oryan, A.; Alidadi, S.; Moshiri, A.; Maffulli, N. Bone regenerative medicine: Classic options, novel strategies, and future directions. *J. Orthop. Surg. Res.* **2014**, *9*, 18. [CrossRef] [PubMed]
10. Asa'ad, F.; Pagni, G.; Pilipchuk, S.P.; Giannì, A.B.; Giannobile, W.V.; Rasperini, G. 3D-Printed Scaffolds and Biomaterials: Review of Alveolar Bone Augmentation and Periodontal Regeneration Applications. *Int. J. Dent.* **2016**, *2016*, 1239842. [CrossRef]
11. Laino, L.; Iezzi, G.; Piattelli, A.; Lo Muzio, L.; Cicciù, M. Vertical ridge augmentation of the atrophic posterior mandible with sandwich technique: Bone block from the chin area versus corticocancellous bone block allograft—Clinical and histological prospective randomized controlled study. *BioMed Res. Int.* **2014**, *2014*, 982104. [CrossRef]
12. Simion, M.; Jovanovic, S.A.; Tinti, C.; Benfenati, S.P. Long-term evaluation of osseointegrated implants inserted at the time or after vertical ridge augmentation. A retrospective study on 123 implants with 1–5 year follow-up. *Clin. Oral Implant. Res.* **2001**, *12*, 35–45. [CrossRef]

13. Khoury, F.; Doliveux, R. The Bone Core Technique for the Augmentation of Limited Bony Defects: Five-Year Prospective Study with a New Minimally Invasive Technique. *Int. J. Periodontics Restor. Dent.* **2018**, *38*, 199–207. [CrossRef] [PubMed]
14. Yang, Y.; Yang, H.; Pan, H.; Xu, J.; Hu, T. Evaluation and New Classification of Alveolar Bone Dehiscences Using Cone-beam Computed Tomography in vivo. *Int. J. Morphol.* **2015**, *33*, 361–368. [CrossRef]
15. Dominiak, M.; Hnitecka, S.; Olchowy, C.; Olchowy, A.; Gedrange, T. Analysis of alveolar ridge width in an area of central lower incisor using cone-beam computed tomography in vivo. *Ann. Anat.* **2021**, *236*, 151699. [CrossRef]
16. Dominiak, M.; Dominiak, S.; Targonska, S.; Gedrange, T. Three-Dimensional Bone Block Planning for Mandibular Sagittal Bone Defect Reconstruction. *J. Healthc. Eng.* **2020**, *2020*, 8829288. [CrossRef]
17. Dressler, D.; Saberi, F.A. Botulinum toxin: Mechanisms of action. *Eur Neurol.* **2005**, *53*, 3–9. [CrossRef]
18. Stimmelmayr, M.; Allen, E.P.; Gernet, W.; Edelhoff, D.; Beuer, F.; Schlee, M.; Iglhaut, G. Treatment of gingival recession in the anterior mandible using the tunnel technique and a combination epithelialized-subepithelial connective tissue graft-a case series. *Int. J. Periodontics Restor. Dent.* **2011**, *31*, 165–173.
19. Dohan, D.M.; Choukroun, J.; Diss, A.; Dohan, S.L.; Dohan, A.J.; Mouhyi, J.; Gogly, B. Platelet-rich fibrin (PRF): A second-generation platelet concentrate. Part I: Technological concepts and evolution. *Oral Surg. Oral Med. Oral Pathol. Oral Radiol. Endod.* **2006**, *101*, 37–44. [CrossRef]
20. Rasperini, G.; Pilipchuk, S.P.; Flanagan, C.L.; Park, C.H.; Pagni, G.; Hollister, S.J.; Giannobile, W.V. 3D-printed Bioresorbable Scaffold for Periodontal Repair. *J. Dent. Res.* **2015**, *94*, 153–157. [CrossRef] [PubMed]
21. Kloss, F.R.; Offermanns, V.; Kloss-Brandstätter, A. Comparison of allogeneic and autogenous bone grafts for augmentation of alveolar ridge defects-A 12-month retrospective radiographic evaluation. *Clin. Oral Implant. Res.* **2018**, *29*, 1163–1175. [CrossRef] [PubMed]
22. Blume, O.; Donkiewicz, P.; Back, M.; Born, T. Bilateral maxillary augmentation using CAD/CAM manufactured allogenic bone blocks for restoration of congenitally missing teeth: A case report. *J. Esthet. Restor. Dent.* **2019**, *31*, 171–178. [CrossRef] [PubMed]
23. Chaushu, G.; Mardinger, O.; Peleg, M.; Ghelfan, O.; Nissan, J. Analysis of complications following augmentation with cancellous block allografts. *J. Periodontol.* **2010**, *81*, 1759–1764. [CrossRef] [PubMed]
24. Khoury, F. *Bone Augmentation in Oral Implantology*; Quintessence Publishing Co Ltd.: London, UK, 2007.

8.4. Publikacja 4: An innovative method for three-dimensional bone reconstruction of the anterior mandible with preserved dentition using an allogeneic bone block: A 6-month follow-up.

AHEAD OF PRINT

An innovative method for three-dimensional bone reconstruction of the anterior mandible with preserved dentition using an allogeneic bone block: A 6-month follow-up

Sylwia Hnitecka[1,A–F], Marzena Dominiak[2,A,E,F], Cyprian Olchowy[3,D–F], Tomasz Gedrange[4,5,A,E,F]

[1] Department of Maxillofacial Surgery, Wroclaw Medical University, Poland
[2] Department of Dental Surgery, Wroclaw Medical University, Poland
[3] Collegium Medicum, Jan Długosz University in Częstochowa, Poland
[4] Department of Oral Surgery, Wroclaw Medical University, Poland
[5] Department of Orthodontics, Dresden Medical University, Germany

A – research concept and design; B – collection and/or assembly of data; C – data analysis and interpretation; D – writing the article; E – critical revision of the article; F – final approval of the article

Advances in Clinical and Experimental Medicine, ISSN 1899–5276 (print), ISSN 2451–2680 (online) *Adv Clin Exp Med*. 2025

Address for correspondence
Sylwia Hnitecka
E-mail: sylwia.hnitecka@gmail.com

Funding sources
None declared

Conflict of interest
None declared

Acknowledgements
The authors want to express their gratitude to Dr. Krzysztof Kujawa from the Centre for Statistical Analysis at Wroclaw Medical University for his valuable insight regarding the statistical analyses.

Received on December 11, 2023
Reviewed on January 2, 2024
Accepted on June 10, 2024

Published online on August 9, 2024

Cite as
Hnitecka S, Dominiak M, Olchowy C, Gedrange T. An innovative method for three-dimensional bone reconstruction of the anterior mandible with preserved dentition using an allogeneic bone block: A 6-month follow-up [published online as ahead of print on August 9, 2024]. *Adv Clin Exp Med*. 2025. doi:10.17219/acem/189840

DOI
10.17219/acem/189840

Abstract

Background. Bone defects around the teeth affect a large portion of the population. Bone regeneration in the area of existing teeth is completely different from that in an edentulous area. To date, no method has been developed for three-dimensional (3D) bone reconstruction in regions with preserved teeth.

Objectives. This study aimed to radiologically evaluate the results of the new method of 3D mandibular bone reconstruction in preserved dentition using a custom-made allogeneic bone block with a 6-month follow-up.

Materials and methods. Alveolar ridge dimensions were radiographically assessed before and 6 months after reconstruction using cone beam computed tomography (CBCT) scans in 32 patients (192 teeth). Reconstruction used a bone block that had been previously planned and prepared using CAD/CAM technology.

Results. The observed changes in alveolar bone dimensions were highly significant in most cases ($p < 0.001$). The closer to the tooth root apex, the lower the bone growth in the sagittal dimension (average of the mean values for each tooth examined in the measured heights): CEJ2: 2.9 mm, ½ CEJ2: 2.7 mm, ¼ CEJ2: 1.9 mm, and API: 1.4 mm. The maximum bone growth in the vertical dimension was observed on tooth 43 (9.9 mm), followed by 32 (9.8 mm), 33 (8.5 mm), 31 (8.4 mm), 42 (8 mm), and 41 (7 mm). The degree of decrease in vestibular dehiscence of the bone was greater the closer the tooth was to the midline (average of −3.8 mm and −3.4 mm for the central incisors; average of −2.8 mm and −2.6 mm for the lateral incisors; average of −2.6 mm and −2.5 mm for the canines).

Conclusions. The results prove that it is possible to prevent bone dehiscence in patients undergoing orthodontic treatment, increasing the ability and effectiveness of covering recessions and improving the morphology of the lower part of the face.

Key words: allograft, mandibular reconstruction, allogeneic bone block, bone reconstruction, orthodontics

Background

A variety of techniques and materials can be found in the available literature, and their continuous improvement is aimed at increasing the effectiveness of alveolar bone regeneration procedures. The methods reported use bone granules, chips, wedges, bone rings, plates, and blocks, including individualized ones, among other things. The effects of using autogenous and allogeneic bone, as well as xenogenous and alloplastic materials, are constantly being compared.[1–5]

However, these procedures are based on achieving the effect of bone growth in edentulous sections of the alveolar process, mainly as preimplantation preparation. To date, many cases have been evaluated and described that bone regeneration in edentulous sections is currently considered a predictable procedure, provided that certain rules are followed.[2] The situation of bone regeneration in areas with existing teeth is completely different.

Dental reports on the regeneration of periodontal vertical bone defects (intrabony) confirm the possibility of achieving satisfactory results.[6–8] Nevertheless, the three-dimensional (3D) regeneration of the alveolar ridge in the dental area poses a problem, especially when it comes to regeneration in the vertical dimension.

It is important to address this issue and look for solutions because the problem of bone defects around the teeth affects a large part of the population.[9,10] This problem becomes especially important when orthodontic treatment is required or when advanced gingival recessions need to be covered.[11–13]

It turns out that the procedures for adequate bone regeneration require careful planning and consideration not only of the type of graft material and its ready-to-use form but also of the surrounding anatomy, with special attention to the quality and quantity of the soft tissues and the function of the surrounding muscles.[14,15]

In this article, we present a novel and innovative method for 3D bone reconstruction of the anterior mandible with preserved dentition using an allogeneic bone block (ABB), focusing on the method of appropriate patient qualification, treatment planning, and the necessary preparatory steps for the basic bone regeneration procedure.

Objectives

This prospective, nonrandomized study aimed to radiologically evaluate the results of a 3D bone reconstruction method for the anterior mandible with preserved dentition with a 6-month follow-up. The main goal was to measure changes in bone dimensions in the anterior mandible based on preoperative cone beam computed tomography (CBCT) analysis and after 6 months.

Materials and methods

Study group

The analysis included data from CBCT scans and the medical records of 32 patients who had undergone anterior mandibular reconstruction surgery using a 3D ABB (as below) and appeared for a 6-month follow-up and CBCT scan. Patients were treated in a private dental practice in Wrocław, Poland, between 2018 and 2021.

Participants were initially referred for surgical consultation for the following reasons:

1. Clinically confirmed gingival recession and consecutive radiographically visible bone defects in the alveolar part of the mandible – both in patients who have never received orthodontic treatment and in those undergoing and following orthodontic treatment. 2. Radiologically identified bone defects without concomitant gingival recession in patients who had a CBCT prior to orthodontic treatment, taking into account the movements of the anterior mandibular teeth.

The analysis included adult (non-growing) patients with preserved dentition, at least in the anterior mandible (teeth 33–43), who had signed an informed consent form for the procedure and participation in the study. This study included patients with bone defects covering the anterior region of the mandible in the area of teeth 33–43 (from the right canine to the left canine) with various configurations and the advancement of dehiscence and/or fenestration.

Patients undergoing orthodontic treatment were also included. In these patients, tooth movements in the analyzed area were suspended for the duration of surgical treatment (passive treatment for 6 months). Smoking patients were advised to give up smoking and were informed about its possible negative effects on healing. Diabetics were also not excluded from the study, provided the disease was stable. There was no upper age limit.

The exclusion criteria included systemic diseases and drug treatments that could affect bone tissue (e.g., Paget's disease, osteoporosis, use of bisphosphonates, or denosumab), previous surgical and periodontal treatments in the anterior mandible, craniofacial anomalies, and previous trauma to the mandible. Patients who did not report for the control CBCT 6 months after reconstruction (4 patients) were also not evaluated.

The primary goal was to quantify bone growth in a population that had a similar procedure performed in a standardized way – values that could be reliably compared.

Research components

The clinical examination mainly included periodontal assessment, identification of possible periodontal pockets (probing depth >4 mm), presence and advancement of the gingival recession, biotype, presence of calculus

Fig. 1. Initial clinical situation of the example patient. Prominent alveolar yokes are visible

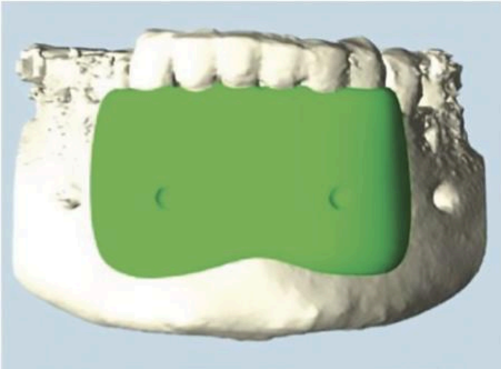


Fig. 2. Bone block planning based on cone beam computed tomography (CBCT). The defect planning is divided into 5 regions (4 external and 1 internal). The position of the screws was taken into account in the planning

and plaque, abnormal frenal attachments (especially on the lower lip), and mentalis muscle tension. It was also determined if the patient had received orthodontic treatment and what type of malocclusion it was, as well as if a gingival graft was required (connective tissue graft (CTG) or free gingival graft (FGG) or both) (Fig. 1).

To adequately prepare and manage the patient, the FLOS concept was developed. This approach consists of physiotherapy, speech therapy, osteopathy, and dental procedures if it's required, due to:

1. a lot of tension of facial muscles and the floor of the mouth from a short lingual frenulum,[16,17]
2. infantile types of swallowing and other similar,
3. wrong posture,[18] and
4. non-carious lesions such as wedge defects or abfraction defects.

The ABB was prepared and obtained in the patented manner presented in the previous article.[19] Briefly, precise cephalometric measurements were first performed with the calculation of the ANB angle and the determination of the face type, since the value of the ANB angle after reconstruction should not exceed 4–5°. The position of the incisors and mandible and the inclination of the mandibular incisors were assessed. The relationship between the maxillary and mandibular incisors was also considered. The crestal bone level was the decisive parameter. In cases undergoing or planning to undergo orthodontic treatment, bone loss should also be predicted in relation to tooth movement. Therefore, the ALi-CEJ2-B angle was measured. Three points were marked: the deepest concavity on the anterior surface of the mandibular symphysis (point B), the apical point of the anteriormost mandibular central incisor (Iia), and the point 2 mm apical to the cementoenamel junction (CEJ) of the incisor, which reflects the sulcus depth.

The CBCT scans played a special role in planning the bone block. The area of the bone defect was divided into 4 external regions and 1 internal region, and the reference points were set on the recipient bed. The point is that the bone graft must be very suitable. Therefore, the internal surface of the block was assessed to make the contact area with the underlying bone as wide as possible (Fig. 2).

Target values were updated to include actual reference point values, and a new range of target values was added to the diagnostic defect area. The bone block body was connected to the first analyzed plane of the mandibular segments with the bone block used. The shape of the chin and the design of the block were also determined. It was important to keep the thickness of the block similar to the thickness of the possible physiological bone regeneration. In addition, the longitudinal axes of the basal symphysis and alveolar symphysis were positioned as parallel to each other as possible, and the total angle created between them did not exceed 10°. The shape of the chin and the design of the block were also checked.

The size of the ABB depended on the size of the bone defect. The assessment was made by the surgeon based on the analysis of the horizontal cross-section of the alveolar process and objectively by orthodontic analysis. The width was assessed from the right to the left canine to ensure that it matched the shape of the mandible in all dimensions. The incisor crowns were measured, and the value determined the arch shape between the canines. The position of the teeth and the mandibular alveolar region were drawn on CBCT scans, and the desired size of the arch was added.

The height of the bone block was determined using 2 measurements in the direction of the crown and the apex, while the level of the crestal bone was positioned 2–3 mm below the CEJ level, which corresponds to the biological width of teeth with healthy periodontium.

The final step was computer-aided design and fabrication (CAD/CAM). A virtual model of the mandible was created by converting CBCT scans and intraoral scans into digital models. A bone block design was placed on the model, and the actual and nominal points were combined to form

Table 1. Clinical steps for preparing the bone block recipient bed

Protocol for 3D bone reconstruction	
1. With recessions	
a. FLOS technique and botox injection in mental muscle – big tension	12–2 weeks before surgery
b. cutting of high attachment of frenum – lingual, buccal, central	4 weeks before surgery
1.1 free gingival graft – is required when are II–IV Miller class of recessions, shallow vestibule	12 weeks to next ST or bone procedure
1.2. soft tissue augmentation	12 weeks to bone surgery
a. thin biotype – superficial connective tissue graft (CTG)	
b. thick biotype – subepithelial CTG	
1.3. 3D bone block- severe loss of the bone	6 months to ortho treatment
2. Without recessions	
a. FLOS technique and botox injection in mental muscle – big tension	12–2 weeks before surgery
b. cutting of high attachment of frenum – lingual, buccal, central	weeks before surgery
1.1. deepening of vestibule – is required when shallow vestibule is present – FGG	4 weeks to next ST or bone procedure
1.2. soft tissue augmentation	12 weeks to bone surgery
a. thin biotype – superficial CTG	
1.3. 3D bone block – severe loss of the bone	months to ortho treatment

ST – soft tissue; CTG – connective tissue graft.

a single unit. A suitable living donor was selected based on adequate cancellous and/or cortical bone volume with the correct bone density. After milling, the block was cleaned, packaged, sterilized, and sent to the surgeon.

Each patient was operated on in the same way and by the same surgeon. Before bone reconstruction was started, it was determined whether the condition of the soft tissues was sufficient. If the biotype was too thin and gingival recession was advanced, FGG and/or CTG were used first (3 months before bone reconstruction). Excessive tension of the mentalis muscle with a specific "orange peel" sign was reduced with an intramuscular injection of botulinum toxin (Table 1).

Bone reconstruction was performed under local anesthesia and with an antibiotic (0.6 g clindamycin) administered orally 1 h before the procedure. First, an intrasulcular incision was made that was 2 spaces wider mesially and distally than the planned reconstruction area, and the mucoperiosteal flap was elevated above the mental eminence to create a catch bed without excessive tension. The bone dehiscences and concavities of the mandibular alveolar region were then exposed (Fig. 3). The root surfaces were then mechanically cleaned of debris, and a surgical drill was used to decorticate the compact bone in the interdental spaces to improve vascularization. The advanced platelet-rich fibrin (PRF) membranes (A-PRF)[20] were prepared using the patient's peripheral blood and placed on the surface. Allogeneic bone particles were placed in the deepest bone defects, followed by the insertion of an individualized 3D block of allogeneic bone. The ABB was stabilized in the desired position with 2 titanium screws (Fig. 4), which were removed after 6–8 weeks. Screws approx. 8 mm in length were used. The A-PRF membranes were placed on the outer surface of the block, and sometimes a pure resorbable collagen

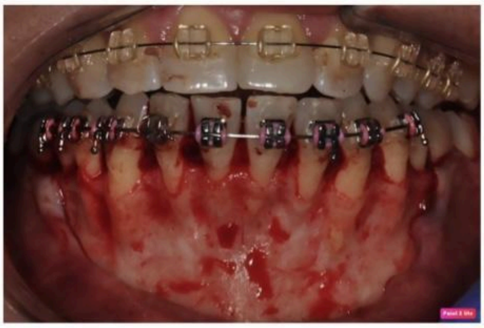


Fig. 3. View after mucoperiosteal flap elevation. Advanced bone dehiscences, fenestrations and exposed tooth roots are visible

Fig. 4. View of the block after fixation with titanium screws to the bone base

barrier membrane previously soaked with a liquid fraction of PRF (i-PRF) was placed apically. The final stage was suturing non-resorbable 6-0 sutures using the suspended and mattress suturing technique, which prevents excessive flap tension. An antibiotic, 0.6 g of clindamycin (Clindamycin MIP; MIP Pharma GmbH, Blieskastel, Germany) twice daily and painkillers for 3 days were prescribed. The patient was instructed to perform proper oral hygiene with an antiseptic mouth rinse (Alfa; ATOS, Warsaw, Poland) and to use a soft toothbrush (Elgydium Clinic 7/100; Elgydium Pierre Fabre, Paris, France) for postoperative care. Immediately after the procedure, biostimulation using a Nd:YAG laser (10 Hz, 0.5 W) was performed (TwinLight®; Fotona, Ljubljana, Slovenia). The sutures were removed 2 weeks after the procedure. The whole procedure was performed according to the method patented by Dominiak M. and Gedrange T. (EP3287097B1 , European Patent Office, Munich, Germany, 2016).

All CBCT scans (before and 6 months after surgery) were acquired with the Pax Flex3D Vatech computed tomography system (Vatech Europe, Warsaw, Poland). The mandible center image: field of view (FOV): 80 mm width and 50 mm height. The voxel size was 0.200. All images were analyzed using EzDent-i software (Vatech). Defined parameters were measured in the sagittal plane at the center of the central incisors (teeth 31 and 41), lateral incisors (teeth 32 and 42) and canines (teeth 33 and 43). Only the buccolingual bone dimension was measured in the axial plane. The reference lines were perpendicular to each other, and the vertical line was aligned with the long axis of the tooth. The tooth inclination was not determined.

The width of the alveolar ridge was measured at 4 points on the tooth root: at the CEJ-2 mm level (the crestal bone level of the healthy periodontium), at the root apex, at half-length from CEJ-2 to the apex, and at the quarter-length from CEJ-2 to the apex. It was determined if there was dehiscence (the marginal bone level was below the CEJ-2 mm level). The height was measured from the vestibular (HDV) and/or lingual (HDL) side. It was determined whether vestibular and lingual fenestration were present (FV and FL, respectively). If fenestration was present, its height was measured (HFV and HFL). When the vestibular and lingual bone layers were extremely thin, this was noted separately. The value of this dimension was then determined (HVCL – the height of the vestibular cortical layer and HLCP – the height of the lingual cortical layer). If the level of marginal bone on both sides was below the CEJ-2 (bilateral dehiscence), then the measured width at this level corresponded to the width of the tooth; therefore, the value for the alveolar width was considered to be 0. The buccolingual dimension halfway from CEJ-2 to the apex was measured. This value was determined on the axial section, mesial and distal to the teeth (WAM – width of alveolar bone medial and WAD – width of alveolar bone distal) (Fig. 5). A detailed description of the measurement in such cases has already been described.[9]

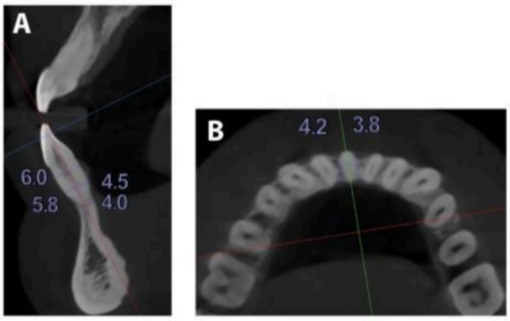


Fig. 5. Scheme of the performance of radiological measurements of the alveolar width – sagittal (A) and axial (B) views

The types and advancement of bone defects were classified according to the classification by Yang et al.[21] and the classification we made (DM classification) as described in another paper.[9] (Fig. 6).

In the radiological assessment, existing dehiscences and lingual fenestrations were also noted, although they were not subject to surgical treatment. The lack of changes after reconstruction is related only to the post-surgical observation of the type of changes in a given area (Fig. 7,8).

Statistical analyses

Bone growth was defined as the difference between the measurements taken after 6 months and before treatment in a given patient (repeated measurements). An additional condition of the study was the interdependence of the given variables within the set of all 6 teeth coming from 1 patient. Furthermore, the distribution of differences between the pre- and post-treatment measurements deviated statistically significantly from the normal distribution in 81% of the tests (Supplementary Table 1). Considering the circumstances described above, the pattern of tooth changes was analyzed using a model for all teeth, for 1 of the 12 variables studied (CEJ2, 1/2CEJ2, etc.), using the R package nparLD,[22] which is a tool for nonparametric analysis of repeated measures data. We used the command 'nparLD': nparLD(data=dane, CEJ2 ~ Time*Tooth, alpha = 0.05, …). The effect size in this test is the "relative treatment effect" (RTE). The model evaluated the statistical significance of Treatment, Tooth, and the Treatment × Tooth effects interactions. The results of running this model for the twelve variables included (1) a table with the statistical significance of the effects (listed above), (2) figures visualizing the effects, and (3) a table with the RTE and its 95% confidence intervals (95% CIs). Since the nparLD does not provide a post hoc test for such a model, the last table above served as the basis for detecting statistically significant differences between before and after treatment measurements.

Due to non-normal data distribution in many of the variables, Spearman's rho rank correlation coefficients were used

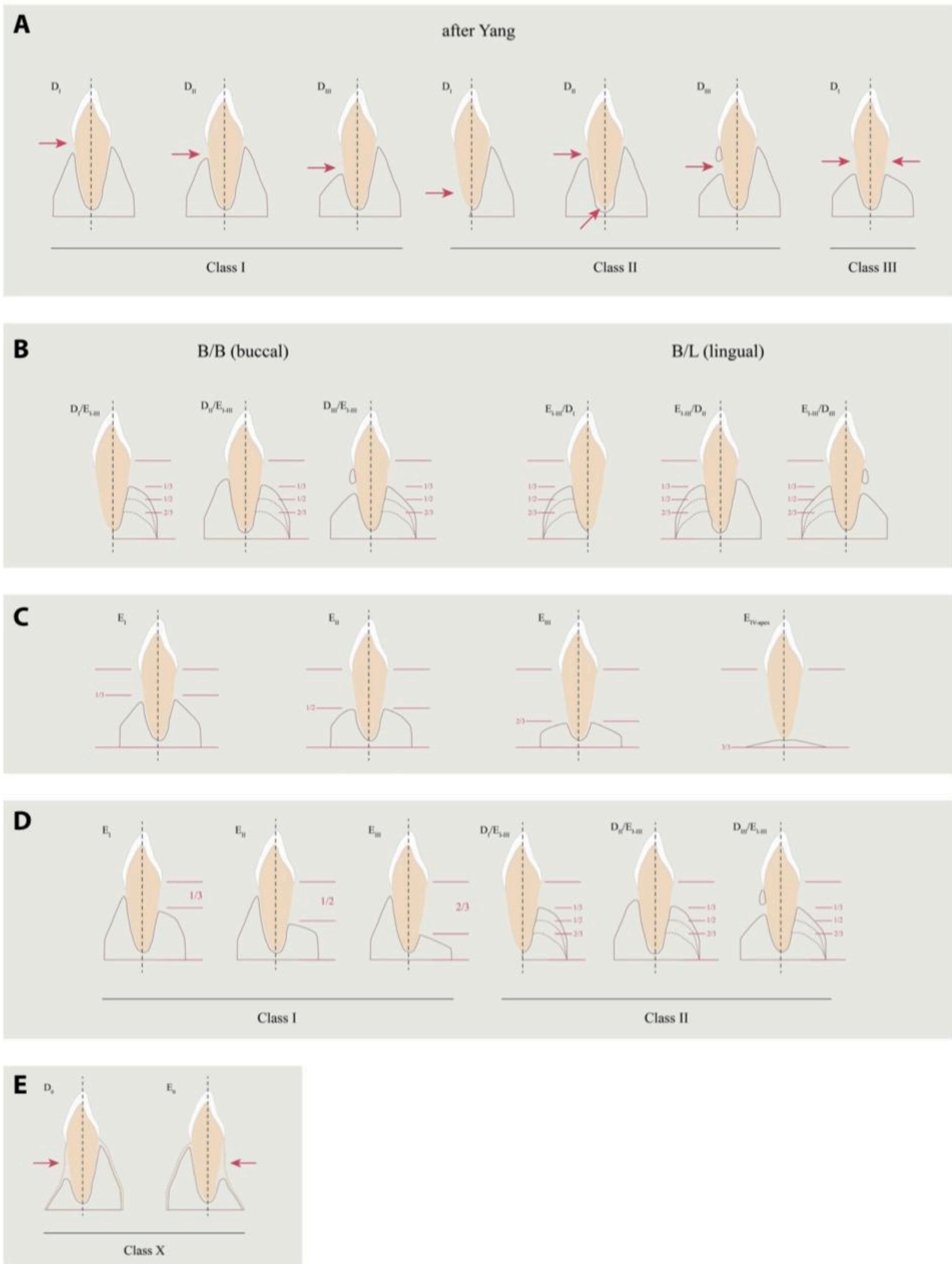


Fig. 6. Yang et al.[21] (A) and DM[9] classifications – class I (B), class II (C), class III (D), and class X (E)

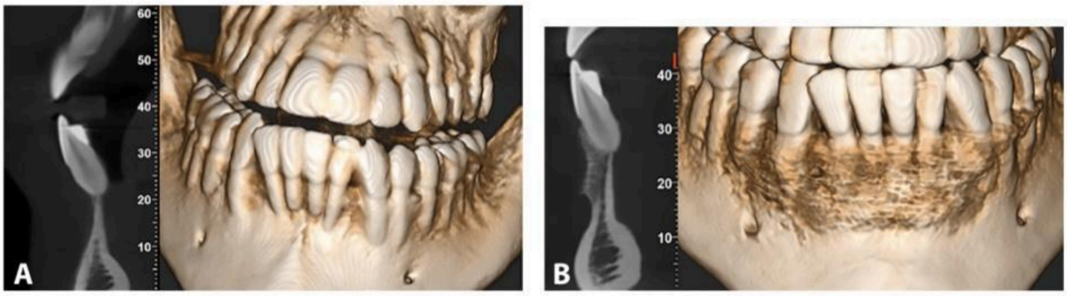


Fig. 7. Cone beam computed tomography (CBCT) scans before (A) and 6 months after bone reconstruction (B) – example patient No. 1

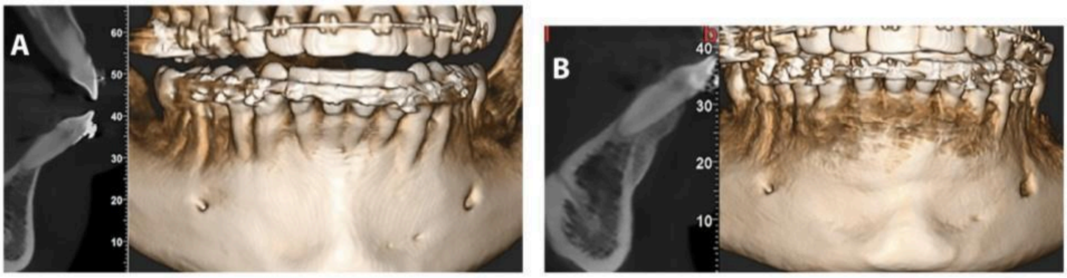


Fig. 8. Cone beam computed tomography (CBCT) scans before (A) and 6 months after bone reconstruction (B) – example patient No. 2

to evaluate the relationship between patient age and changes in bone dimensions. The Shapiro–Wilk test was used to check data distribution normality. Spearman's rho rank correlation coefficients were used to evaluate the monotonic component of the correlation between patient age and changes in bone dimensions. Although the nonparametric test was used in the analysis of the tooth changes, all variables are presented as means and standard deviation (SD), which are more precise than medians and quartiles when tiny changes have occurred. Additionally, the means and median were strongly correlated (Spearman's correlation: $n = 72$, $R = 0.93$, $p < 0.001$), which justifies using the means for presenting bone growth patterns. The statistical description of bone growth parameters is presented in Supplementary Table 2.

The Fisher's exact test was used for the contingency table analysis. As the comparison of bone growth variables between the sexes was considered an exploratory approach in the analysis, no correction for the controlling of Type-I errors was used.

When estimating the required sample size, a postoperative bone growth of at least 1.0 mm, a SD of 1.5 mm and a test power of at least 0.8 were assumed. With these assumptions and an assumed significance level of $\alpha = 0.05$, the minimum sample size was $n = 20$. The selection of patients for the research sample was done successively, and the adequacy of the sample size was continuously checked by estimating the power of the statistical tests used. Patients were included in the research group until the main objective of the study, i.e., bone growth after surgery measured at CEJ2, 1/2CEJ2 and 1/4CEJ2 levels, was achieved with a test power of $1 - \beta = 0.80$.

The lowest growth was observed in tooth 43. For the measured bone growth at the CEJ2 level (1.6 ±3.0), the significance of the test with a sample size of $n = 32$ was 0.832 and thus above the assumed minimum value of 0.8. For the same tooth and an increment of 1/4CEJ2 of 1.1 ±1.3, the significance of the test was 0.996.

Statistical analysis was performed using the R environment (R Foundation for Statistical Computing, Vienna, Austria, https://www.r-project.org) and Statistica v. 13.3 software (TIBCO Software Inc., Palo Alto, USA).

Ethics statement

The study was conducted according to the guidelines of the Declaration of Helsinki, and an approval of the Bioethics Committee of Wroclaw Medical University was obtained (No. KB-284/2023N). The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) checklist was completed.

Results

Overall

The analysis included 32 patients – 25 women (78.1%) and 7 men (21.9%) with a F:M ratio = 1:3.6. Patients' ages

Table 2. The changes in tooth variables as the difference between after and before treatment (means and standard deviation; SD). Statistically significant differences are in bold. Statistical significance was calculated using the Relative Treatment Effect and R-package "nparLD" (see Supplementary Table 3 for details)

Variable	Tooth						Average
	43	42	41	31	32	33	
ΔCEJ2	1.6 ±3.0	**3.3 ±3.5**	**3.9 ±3.2**	**3.0 ±3.3**	**3.2 ±3.7**	2.0 ±3.5	2.9 ±2.1
Δ½CEJ2	**1.1 ±1.8**	**3.3 ±2.5**	**3.4 ±2.4**	**3.4 ±2.7**	**3.2 ±2.8**	**2.8 ±2.0**	2.7 ±1.6
Δ¼CEJ2	**1.1 ±1.3**	**2.4 ±1.9**	**2.4 ±1.8**	**2.4 ±2.1**	**2.1 ±1.5**	**1.2 ±1.3**	1.9 ±1.3
ΔAPI	0.7 ±0.9	**1.8 ±1.3**	**1.8 ±1.1**	**1.7 ±1.1**	**1.6 ±1.2**	0.8 ±0.9	1.4 ±0.8
ΔHD1	**−2.6 ±3.1**	**−2.6 ±2.9**	**−3.4 ±2.3**	**−3.8 ±2.3**	**−2.8 ±2.8**	**−2.5 ±3.0**	−2.9 ±1.8
ΔHD2	−0.0 ±0.1	−0.1 ±0.2	0.1 ±0.7	−0.1 ±0.2	−0.0 ±0.1	0.0 ±0.1	−0.0 ±0.1
ΔHBP	**−0.1 ±1.7**	**−0.4 ±1.9**	**−0.5 ±1.3**	**−0.3 ±1.5**	−0.8 ±1.6	−1.0 ±2.1	−0.5 ±0.8
ΔHBJ	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	−0.1 ±0.5	0.0 ±0.0	−0.2 ±0.9	−0.0 ±0.2
ΔHF1	**−0.9 ±2.1**	**−0.8 ±1.6**	−0.2 ±1.5	0.0 ±0.2	−0.8 ±1.6	−0.4 ±2.1	−0.5 ±1.1
ΔHF2	0.0 ±0.0	−0.0 ±0.0	−0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	−0.0 ±0.0
ΔWAM	**1.6 ±1.1**	**2.4 ±1.4**	**2.4 ±1.3**	**2.3 ±1.5**	**2.2 ±1.6**	**1.9 ±1.4**	2.1 ±1.0
ΔWAD	**1.2 ±1.0**	**2.1 ±1.1**	**2.7 ±1.6**	**2.1 ±1.2**	**2.1 ±1.3**	**1.4 ±1.1**	1.9 ±0.9

ranged from 18 to 50 years at the time of the procedure; the mean was 32.1 ±9.2 years.

The largest study group consisted of patients after orthodontic treatment (n = 10; 31.25%; mean age of 35.5 years), followed by study participants before planned orthodontic treatment (n = 9; 28.1%; mean age of 33.5 years) and during orthodontic treatment (n = 9; 28.1%; mean age of 31.6 years). On the other hand, orthodontic treatment was not planned in only 4 study participants (12.5%, mean age of 34 years) who had not been treated previously.

The results of the procedures are shown in Fig. 7,8 using the example of selected patients from the studied group.

The observed changes in alveolar bone dimensions (Table 2) were statistically significant in most variables except for the level of lingual dehiscence (ΔHD2), lingual cortical bone (ΔHBJ) and FL (ΔHF2) (Table 3). The analysis was performed using the R-package nparLD. Among the 9 variables statistically significantly affected by Time (i.e., treatment), no interactions with teeth occurred in 2 variables only (CEJ2 and HBP). In the case of the other variables, such interactions were statistically significant, which means that the changes differed between some teeth (Fig. 9, Supplementary Table 3).

The closer to the tooth root apex, the lower the bone growth in the sagittal dimension. Average of the mean values for each analyzed tooth in the measured heights: CEJ2: 2.9 mm, ½ CEJ2: 2.7 mm, ¼ CEJ2: 1.9 mm, and API: 1.4 mm.

In the sagittal dimension, the level at the:

– CEJ2 had the highest average bone growth at tooth 41 (3.9 mm) and the lowest at 43 (1.6 mm),

– ½ CEJ2 had the highest average bone growth at 31 and 41 (3.4 mm) and the lowest at 43 (1.1 mm),

– ¼ CEJ2 had the highest average bone growth at teeth 31, 41, and 42 (2.4 mm) and the lowest at 43 (1.1 mm), and

– API found the highest average bone growth at 41 and 42 (1.8 mm) and the lowest at 43 (0.7 mm).

Maximum bone growth in the vertical dimension was found at tooth 43 (9.9 mm), followed by 32 (9.8 mm), 33 (8.5 mm), 31 (8.4 mm), 42 (8 mm), and 41 (7 mm).

The degree of decrease in vestibular dehiscence of the bone was greater the closer the tooth was to the midline (average −3.8 mm and −3.4 mm for central incisors, 31 and 41, respectively; average −2.8 mm and −2.6 mm for lateral incisors, 32 and 42, respectively; and average −2.6 mm and −2.5 mm for canines 43 and 33, respectively).

The presence of an extremely thin cortical plate before reconstruction was noted in 26 of 192 teeth examined (13.5%) and FV in 28 cases (14.6%). The average height of the vestibular plate was 4.3 mm, while the height of the fenestration plate was 4.1 mm.

Due to the lack of surgical intervention on the lingual side and the elimination of possible orthodontic movements in patients with braces, no differences in the dimensions of bone dehiscences and fenestrations were observed (only values of ±max 0.2 mm, mainly due to measurement errors).

Tangential to the mesial surface of the tooth at the level of ½ CEJ2, the average bone increment in the sagittal dimension (WAM) was 2.1 mm and was greatest at teeth 41 and 42, while distal (WAD) averaged 1.9 mm and was also greatest at tooth 41.

Analysis of the influence of age and sex

There was no statistically significant correlation between patient age and bone growth in any of the variables studied (Supplementary Table 4). There was also no statistically significant difference between men and women in terms of bone growth (Supplementary Table 5).

Table 3. Statistical significance of time ("after" vs "before"), tooth and interaction time × tooth for treatment effects measured with the use of variables CEJ2, 1/2CEJ2, etc. The analysis was performed using the R-package nparLD (see the section "Statistical analyses" for details)

Explained variable	Effect	Statistic	df	p-value
CEJ2	time	62.09	1	<0.001
	tooth	21.49	3.20	<0.001
	time:tooth	1.8	3.98	0.127
1/2CEJ2	time	149.81	1	<0.001
	tooth	27.3	2.69	<0.001
	time:tooth	17.3	3.32	<0.001
1/4CEJ2	time	147.93	1	<0.001
	tooth	20.11	3.48	<0.001
	time:tooth	11.35	3.31	<0.001
API	time	106.77	1	<0.001
	tooth	7.98	3.08	<0.001
	time:tooth	11.63	3.67	<0.001
HD1	time	92.17	1	<0.001
	tooth	3.72	3.32	0.008
	time:tooth	2.41	3.87	0.049
HD2	time	0.45	1	0.504
	tooth	14.66	3.44	<0.001
	time:tooth	0.7	1.69	0.472
HBP	time	12.13	1	<0.001
	tooth	0.36	4.51	0.858
	time:tooth	1.27	4.11	0.280
HBJ	time	1.84	1	0.175
	tooth	0.88	1.89	0.411
	time:tooth	1.65	1.41	0.198
HF1	time	6.81	1	0.009
	tooth	2.78	3.99	0.026
	time:tooth	2.56	3.88	0.038
HF2	time	2.07	1	0.151
	tooth	0.68	1.72	0.484
	time:tooth	0.79	1.90	0.446
WAM	time	160.27	1	<0.001
	tooth	25.2	3.64	<0.001
	time:tooth	5.09	4.27	<0.001
WAD	time	159.63	1	<0.001
	tooth	22.39	3.40	<0.001
	time:tooth	12.72	4.24	<0.001

df – degrees of freedom.

The average bone growth in the group of patients who underwent orthodontic treatment with a passive archwire and in the group of patients without ongoing orthodontic treatment did not differ significantly except for HBJ and HF2, in which small and marginally statistically significant differences occurred (Supplementary Table 6).

Analysis of the impact of adverse features (gingival recessions, thin biotype, excessive function of the mentalis muscle)

Before treatment, the presence of the above factors that might affect the final treatment effect was determined.

In 22 (68.75%) of the cases, the gingival biotype was thin at baseline. The same number of participants (n = 22; 66.75%) were diagnosed with significant gingival recession. Almost half of the patients (n = 14; 43.75%) showed mentalis muscle hyperactivity.

The chance of achieving an optimal therapeutic effect was 4 times greater in the group of patients without recessions than in the group with recessions (OR = 4.20), but the 95% CI was (0.44–39.9) at a p = 0.38 using Fisher's exact test, which should be interpreted as equal chances of an optimal outcome in both groups (not significantly dependent on the presence of recessions). There was no statistically significant difference between patients differing in the occurrence of recessions in relation to bone growth except for marginal significance for HF2 (Supplementary Table 7). A similar lack of dependence was seen in the patient groups with thick and thin biotypes (except for the marginal significance of HBJ) (Supplementary Table 8) and excessive mentalis muscle tension (Supplementary Table 9). Considering the above presentation of the method of preparing the patient for the procedure, the absence of these effects proves the proper implementation of the adopted algorithm – among other recession coverages and elimination of tension.

Predicting optimal treatment effect

The ideal therapeutic effect is evidenced by the ADI class according to DM after treatment. The assessment of treatment outcomes did not take into account the condition of the tissues on the lingual side. This effect was obtained in 24 (75%) patients. In the remaining patients, the ADI class was not definitively achieved, but the therapeutic effect was satisfactory.

The "gold standard" for optimal therapeutic effect was the DM classification, based on which patients were divided into 1 of 2 groups with ideal or satisfactory effects. Continuous variables such as age and changes in bone dimensions after 6 months of treatment were transformed into dichotomous (binary) variables, with cutoff values based on the analysis of receiver operating characteristic (ROC) curves. Patient age is a destimulating (reducing) variable for the chance of achieving an optimal treatment effect. As age increases, the probability of achieving an optimal therapeutic effect decreases. For an age cutoff ≥34 years, Sensitivity (Sens.) = 79.2%, Specificity (Spec.) = 75.0%, Accuracy (Acc.) = 78.1%, PPV = 90.5; Likelihood Ratio (+) = 3.17.

The ideal treatment effect was more frequent in the case of an increase in the:

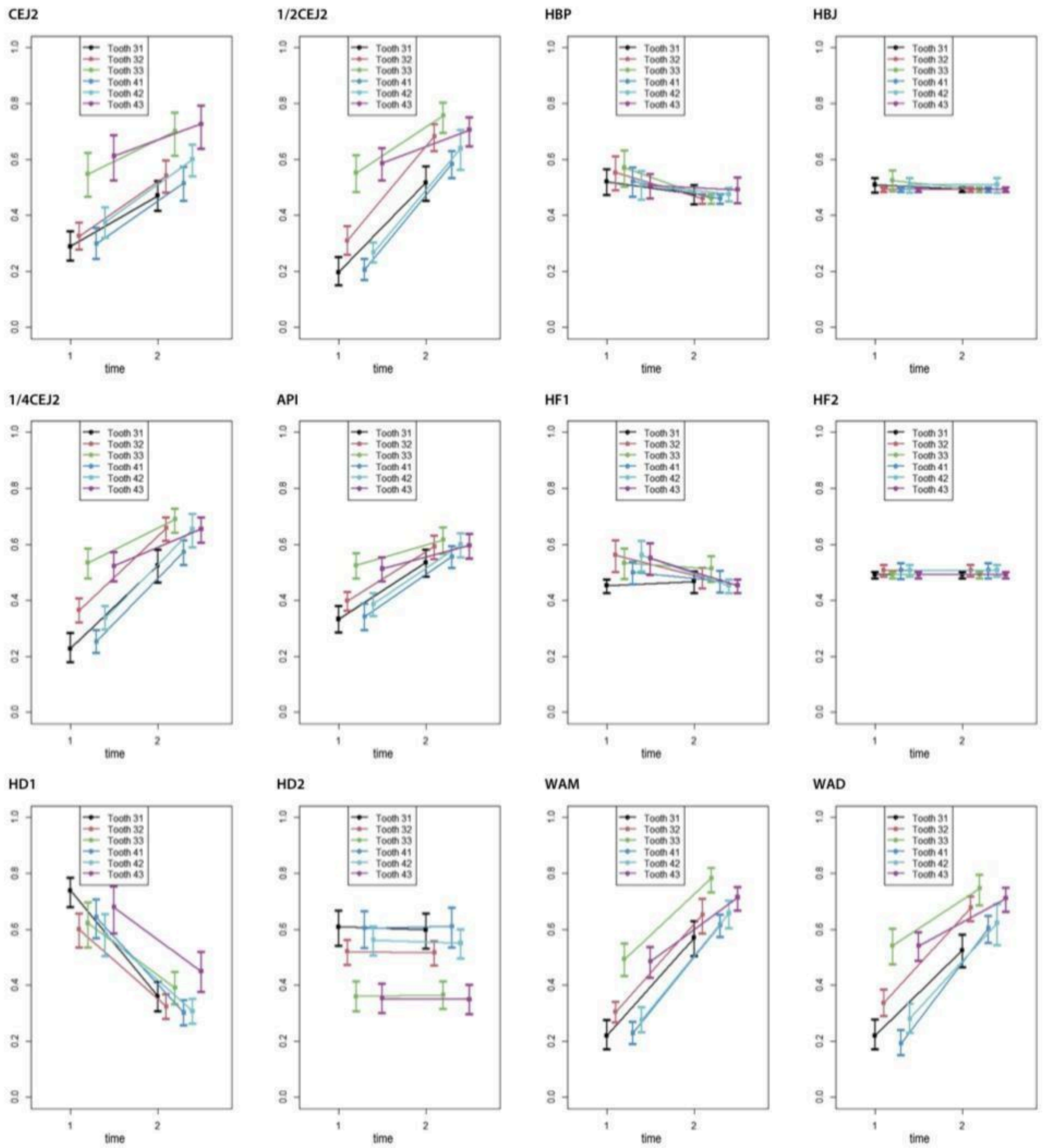


Fig. 9. Relative treatment effect (1 – measurements before treatment; 2 – measurements after treatment) with 95% confidence intervals (95% CIs), calculated with the use of R-package nparLD (see Supplementary Table 2 for details and statistical significance of the differences)

– ΔCEJ2 of tooth 31 by at least 0.5 mm, tooth 41 by 0.4 mm and tooth 42 by 0.1 mm;

– ½ CEJ2 of tooth 41 by at least 5.9 mm and of tooth 42 by 3.0 mm;

– ¼ CEJ2 of tooth 32 by at least 1.6 mm; and

– WAM tooth 33 by at least 2.1 mm.

Discussion

Orthodontic treatment is currently very common in a significant percentage of dental patients, regardless of age. It is well known that proper and effective tooth movement requires the presence of an adequate amount and quality of bone. Induced tooth movement should only be carried out at the alveolar bone trabeculae.[12] Unfortunately, the occurrence of a gingival recession is still a common side effect. One of the basic assumptions is that the thickness of the anterior part of the alveolar bone should be considered as a limiting factor for orthodontic treatment. Exceeding these anatomical limits is associated with an increased risk of bone loss and the formation of alveolar defects – dehiscences and fenestrations. Anterior teeth in the mandible are found to be most susceptible to these problems, and it has also been observed that the greatest treatment-related bone loss occurred on the side to which a tooth was moved.[23] In addition, pre-existing bone defects often act as "predisposing factors" for gingival recession.[12]

An exposed root surface due to gingival recession is often associated with dentin hypersensitivity, root caries, noncarious cervical lesions, impaired plaque control, and unaesthetic appearances. In addition, untreated gingival recession can lead to further apical displacement over time if the patient does not behave correctly.[24] It would be much better to prevent a recession as much as possible.

In the absence of similar methods developed for the purpose described, the analysis of the effectiveness evaluation focuses on the results obtained. First, it is necessary to consider why the ABB and CAD/CAM technology were used and what conditions must be met to achieve a satisfactory effect.

Allografts are a commonly used graft material nowadays. They come from a donor of the same species, which can be fresh frozen, freeze-dried or demineralized freeze-dried bone. This material may not only serve as an osteoconductive scaffold for new bone formation but may also have some osteoinductive potential due to the presence of proteins such as bone morphogenetic proteins.[25] No donor site morbidity, less postoperative discomfort, a much larger bone availability, and less bone resorption than autologous bone are leading surgeons to increasingly choose this graft material.[26] It is produced and used in various forms, ranging from tiny granules to large 3D blocks.

Brugnami et al. showed that the combination of corticotomy and guided bone regeneration (GBR) in orthodontically treated patients allows for an increase in the dimensions of the "bone envelope" so that the possible deleterious effects of orthodontic movements on periodontal tissues can be overcome, even when the movements are outside the original alveolar anatomy. However, the use of granules with membranes is associated with the movement of the material, the lack of a significantly stable 3D space and a relatively low regeneration potential. Such treatment leads to the formation of a conglomerate of augmentation material so that no new layer of cortical bone is formed with a new point B.[27]

Knowing the excellent properties of allogeneic bone as a graft material, the search for a better and more effective method leads to modifications in the shape and structure of the graft.

As early as the end of the 20th century, the idea of using CAD/CAM technology for the fabrication of onlay blocks in augmentation procedures was presented.[28] This technology allows for a custom fabrication of allogeneic bone blocks for a variety of alveolar ridge augmentation procedures. Many successful cases have been described, highlighting in particular the accuracy, precision and perfect fit of the bone blocks fabricated using CAD/CAM technology.[26]

In our cases, the block was placed directly out of the sterile packaging onto the donor bone with a passive fit. Since no shaping or multiple adjustments were required, the open wound time and overall surgical time were significantly reduced.

The ideal therapeutic effect, as defined by the ADI class according to the DM classification after treatment, was achieved in 24 (75%) patients. In others, the ADI class was not fully reached, but the therapeutic effect was satisfactory. Very satisfactory results of maximum bone growth in the vertical dimensions were obtained because, in some cases, even more than 9 mm were reached.

Before performing the basic bone reconstruction procedure, possible complications and their causes should be considered, and an attempt should be made to eliminate them at the preparatory stage.

Common problems with allogeneic bone blocks include wound dehiscence with exposure of the membrane, opening of the incision and exposure of the bone block. These problems are largely due to poor oral hygiene, pre-existing disease, a thin biotype, and thus poor soft tissue management rather than the allogeneic blocks themselves.[26,29] Therefore, proper soft tissue management should not be a way to treat the above complications but should be an appropriate preparatory phase for advanced bone reconstructions.

Only after the soft tissues (labial side) achieved a stable condition did reconstruction begin. Too thin a biotype, too little keratinized tissue, a shallow vestibule combined with a high and strong frenal attachment, and strong tensions from the mentalis muscle can lead to recession relapse, flap retraction and exposure of the bone block, which could result in a negative outcome, especially during the early phases of healing.[14]

In the group of patients we analyzed, there was no statistically significant difference between the patients who differed in the occurrence of recession in relation to bone growth. A similar lack of dependence was seen in the patient groups with thick and thin biotypes and excessive mentalis muscle tension. However, these results were the result of adequate patient preparation. The above factors, which could have a significant negative impact on the final effect of the procedure, were eliminated by gingival augmentation (CTG, FGG or both), ensuring the correct quantity and quality of soft tissue, the depth of the oral vestibule and the performance of a frenectomy or frenuloplasty, especially in cases of pull syndrome and injections of botulinum toxin into the mentalis muscle. The analysis of the direct influence of the above factors on the effect of reconstruction would have to be based on the division of patients into groups – one group in which the respective factor was eliminated and another in which bone reconstruction was performed with the factor retained. However, this would deliberately expose patients to a worse outcome or to complete failure. The lack of differences is a confirmation of the effectiveness of such preparations of the patient for the procedure.

For the first time, we presented this method as an example of treating a patient with a 6-month follow-up. Finally, the radiographic images revealed the formation of a new layer of cortical bone on the vestibular side and a certain volume of cancellous bone, noting that the block was prepared only from the spongy bone. This is probably related to the way bone blocks are remodeled, which depends on the force and physiological loads acting on them.[30] Similar radiological observations were presented by other authors who also showed the formation of a compact bone layer after a 10-month observation.[31] Hence, the functional adaptation of the bone block to the current morphological and functional conditions is visible. The formation of new cortical bone makes it possible to determine new cephalometric points in this area, especially point D,[32] which is important because it determines the directions of possible future orthodontic treatment.

Limitations

A limitation but also further perspectives of this study would include a longer observation period, an analysis of cases in which the methods were applied in other jaw sections, and a separate analysis of changes in bone dimensions during orthodontic treatment, taking into account the inclination of the teeth as we consider different moments of orthodontics treatment (despite suspension of orthodontic movement for the duration of surgical treatment).

Conclusions

This is the first developed and proven method of 3D bone reconstruction in areas with existing teeth. It creates the possibility of safe and predictable reconstruction of vertical and horizontal alveolar bone in the toothed area above the tooth, increases the long-term results of covering gingival recessions through buccal bone reconstruction, enables the prevention of bone dehiscence in orthodontically treated patients, and improves the morphology of the lower part of the face. It can be successfully performed under local anesthesia. A similar method is worth considering for other areas of the oral cavity.

Supplementary files

The Supplementary materials are available at https://doi.org/10.5281/zenodo.11609828. The package includes the following files:

Supplementary Table 1. The Shapiro –Wilk's normality test (n = 32 for each variable and each tooth) for the differences between before and after the treatment.

Supplementary Table 2. Descriptive statistics of the studied bone growth parameters.

Supplementary Table 3. Relative Treatment Effects for the studied teeth and the statistical significance of the differences between before and after treatment.

Supplementary Table 4. Spearman's correlations of the bone growth parameters (averaged data for all teeth).

Supplementary Table 5. The differences in bone growth parameters (averaged data for all teeth) between sexes.

Supplementary Table 6. The differences in bone growth parameters (averaged data for all teeth) between patients who underwent orthodontic treatment with a passive wire (Wire) and patients without ongoing treatment (Without wire).

Supplementary Table 7. The differences in bone growth parameters (averaged data for all teeth) between patients with recessions (Yes) and patients without recession (No).

Supplementary Table 8. The differences in bone growth parameters (averaged data for all teeth) between patients with thin biotype (Thin) and patients with thick biotype (Thick).

Supplementary Table 9. The differences in bone growth parameters (averaged data for all teeth) between patients with excessive mentalis muscle tension (Yes) and patients without such the feature (No).

Data availability

The datasets generated and/or analyzed during the current study are available from the corresponding author on reasonable request.

Consent for publication

Not applicable.

ORCID iDs

Sylwia Hnitecka https://orcid.org/0000-0002-1171-9817
Marzena Dominiak https://orcid.org/0000-0001-8943-0549
Cyprian Olchowy https://orcid.org/0000-0002-6559-3973
Tomasz Gedrange https://orcid.org/0000-0002-3551-6467

References

1. Jun CM, Yun JH. Three-dimensional bone regeneration of alveolar ridge defects using corticocancellous allogeneic block grafts: Histologic and immunohistochemical analysis. *Int J Periodontics Restorative Dent.* 2016;36(1):75–81. doi:10.11607/prd.1950
2. Sanz M, Vignoletti F. Key aspects on the use of bone substitutes for bone regeneration of edentulous ridges. *Dent Mater.* 2015;31(6):640–647. doi:10.1016/j.dental.2015.03.005

3. Canullo L, Del Fabbro M, Khijmatgar S, et al. Dimensional and histomorphometric evaluation of biomaterials used for alveolar ridge preservation: A systematic review and network meta-analysis. *Clin Oral Invest.* 2022;26(1):141–158. doi:10.1007/s00784-021-04248-1
4. Chavda S, Levin L. Human studies of vertical and horizontal alveolar ridge augmentation comparing different types of bone graft materials: A systematic review. *J Oral Implantol.* 2018;44(1):74–84. doi:10.1563/aaid-joi-D-17-00053
5. Motamedian S, Khojaste M, Khojasteh A. Success rate of implants placed in autogenous bone blocks versus allogenic bone blocks: A systematic literature review. *Ann Maxillofac Surg.* 2016;6(1):78. doi:10.4103/2231-0746.186143
6. Dominiak M, Łysiak-Drwal K, Solski L, Żywicka B, Rybak Z, Gedrange T. Evaluation of healing processes of intraosseous defects with and without guided bone regeneration and platelet rich plasma: An animal study. *Ann Anat.* 2012;194(6):549–555. doi:10.1016/j.aanat.2012.07.007
7. Gupta A, Arora K, Aggarwal P, Kaur K, Mohapatra S, Pareek S. Evaluation of biphasic hydroxapatite and β-tricalcium phosphate as a bone graft material in the treatment of periodontal vertical bony defects: A clinical and digital radiological measurement study. *Indian J Dent Res.* 2022;33(2):152. doi:10.4103/ijdr.IJDR_234_19
8. Kao RT, Nares S, Reynolds MA. Periodontal regeneration – intrabony defects: A systematic review from the AAP Regeneration Workshop. *J Periodontol.* 2015;86(2 Suppl):S77–S104. doi:10.1902/jop.2015.130685
9. Dominiak M, Hnitecka S, Olchowy C, Olchowy A, Gedrange T. Analysis of alveolar ridge width in an area of central lower incisor using cone-beam computed tomography in vivo. *Ann Anat.* 2021;236:151699. doi:10.1016/j.aanat.2021.151699
10. Nimigean VR, Nimigean V, Bencze MA, Dimcevici-Poesina N, Cergan R, Moraru S. Alveolar bone dehiscences and fenestrations: An anatomical study and review. *Rom J Morphol Embryol.* 2009;50(3):391–397.
11. Antoun JS, Mei L, Gibbs K, Farella M. Effect of orthodontic treatment on the periodontal tissues. *Periodontol 2000.* 2017;74(1):140–157. doi:10.1111/prd.12194
12. Jati AS, Furquim LZ, Consolaro A. Gingival recession: Its causes and types, and the importance of orthodontic treatment. *Dental Press J Orthod.* 2016;21(3):18–29. doi:10.1590/2177-6709.21.3.018-029.oin
13. Saminsky M, Meir H, Sebaoun A, Tal H. Positive relationship between the dimensions of clinical gingival recessions and associated alveolar bone dehiscences: A biometric study. *Quintessence Int.* 2022;53(4):308–313. doi:10.3290/j.qi.b2644803
14. Stimmelmayr M, Allen EP, Gernet W, et al. Treatment of gingival recession in the anterior mandible using the tunnel technique and a combination epithelialized-subepithelial connective tissue graft: A case series. *Int J Periodontics Restorative Dent.* 2011;31(2):165–173. PMID:21491016.
15. Melo LGN, Almeida ALPF, Lopes JFS, et al. A modified approach for vestibuloplasty in severely resorbed mandible using an implant-retained postoperative stent: A case report. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod.* 2008;106(4):e7–e14. doi:10.1016/j.tripleo.2008.05.029
16. Murias I, Grzech-Leśniak K, Murias A, et al. Efficacy of various laser wavelengths in the surgical treatment of ankyloglossia: A systematic review. *Life.* 2022;12(4):558. doi:10.3390/life12040558
17. Olivi G, Signore A, Olivi M, Genovese MD. Lingual frenectomy: Functional evaluation and new therapeutical approach. *Eur J Paediatr Dent.* 2012;13(2):101–106. PMID:22762170.
18. Kalecińska E, Dominiak M, Dominiak P, Anwejler J. Postural disturbances in the presence of the dysfunction of the masticatory system: Case report. *Dent Med Probl.* 2004;41:305–312.
19. Dominiak M, Dominiak S, Targonska S, Gedrange T. Three-dimensional bone block planning for mandibular sagittal bone defect reconstruction. *J Healthcare Eng.* 2020;2020:8829288. doi:10.1155/2020/8829288
20. Dohan DM, Choukroun J, Diss A, et al. Platelet-rich fibrin (PRF): A second-generation platelet concentrate. Part I: Technological concepts and evolution. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod.* 2006;101(3):e37–e44. doi:10.1016/j.tripleo.2005.07.008
21. Yang Y, Yang H, Pan H, Xu J, Hu T. Evaluation and new classification of alveolar bone dehiscences using cone-beam computed tomography in vivo. *Int J Morphol.* 2015;33(1):361–368. doi:10.4067/S0717-95022015000100057
22. Noguchi K, Gel YR, Brunner E, Konietschke F. nparLD: An R software package for the nonparametric analysis of longitudinal data in factorial experiments. *J Stat Soft.* 2012;50(12):1–23. doi:10.18637/jss.v050.i12
23. Jäger F, Mah JK, Bumann A. Peridental bone changes after orthodontic tooth movement with fixed appliances: A cone-beam computed tomographic study. *Angle Orthod.* 2017;87(5):672–680. doi:10.2319/102716-774.1
24. Imber JC, Kasaj A. Treatment of gingival recession: When and how? *Int Dent J.* 2021;71(3):178–187. doi:10.1111/idj.12617
25. Sheikh Z, Hamdan N, Ikeda Y, Grynpas M, Ganss B, Glogauer M. Natural graft tissues and synthetic biomaterials for periodontal and alveolar bone reconstructive applications: A review. *Biomater Res.* 2017;21(1):9. doi:10.1186/s40824-017-0095-5
26. Pfaffeneder-Mantai F, Meller O, Schneider B, et al. Specially designed and CAD/CAM manufactured allogeneic bone blocks using for augmentation of a highly atrophic maxilla show a stable base for an all-on-six treatment concept: A case report. *Maxillofac Plast Reconstr Surg.* 2022;44(1):21. doi:10.1186/s40902-022-00351-9
27. Brugnami F, Caiazzo A, Mehra P. Can corticotomy (with or without bone grafting) expand the limits of safe orthodontic therapy? *J Oral Biol Craniofac Res.* 2018;8(1):1–6. doi:10.1016/j.jobcr.2017.11.001
28. Eufinger H. Individual augmentation of the atrophic mandible based on CAD/CAM-manipulated computed tomography data: In vitro results. *Int J Oral Maxillofac Surg.* 1994;23(6):399–402. doi:10.1016/S0901-5027(05)80029-3
29. Chaushu G, Mardinger O, Peleg M, Ghelfan O, Nissan J. Analysis of complications following augmentation with cancellous block allografts. *J Periodontol.* 2010;81(12):1759–1764. doi:10.1902/jop.2010.100235
30. Dominiak M, Hnitecka S, Olchowy C, Dominiak S, Gedrange T. Possible treatment of severe bone dehiscences based on 3D bone reconstruction: A description of treatment methodology. *Appl Sci.* 2021;11(21):10299. doi:10.3390/app112110299
31. Blume O, Donkiewicz P, Back M, Born T. Bilateral maxillary augmentation using CAD/CAM manufactured allogenic bone blocks for restoration of congenitally missing teeth: A case report. *J Esthet Restor Dent.* 2019;31(3):171–178. doi:10.1111/jerd.12454
32. Dominiak M. Własna metoda oceny prognozowania recesji przyzębia [habilitation thesis]. Wrocław, Poland: Wroclaw Medical University; 2009.

9. PODSUMOWANIE WYNIKÓW

9.1. Publikacja 1: Analysis of alveolar ridge width in an area of central lower incisor using cone-beam computed tomography in vivo.

W niniejszej publikacji dowiedziono, że problem występowania ubytków kostnych w zakresie przedniego odcinka uzębionej żuchwy jest bardzo częsty. W dokonanym przez nas badaniu wyniósł bowiem 91%, przy czym u 43% stwierdzono obecność jedynie bardzo cienkiej blaszki przedsionkowej. Wykazano, że u znacznej części społeczeństwa najistotniejszym problemem są dehiscencje wargowe. Różnorodność zaawansowania i konfiguracji defektów- zarówno dehiscencji jak i fenestracji, niekiedy występujących obustronnie, skłoniły autorów do dokonania rozszerzonej modyfikacji klasyfikacji Yang i wsp. [13].

Zwrócono uwagę także na możliwość występowania sytuacji, gdy recesja nie jest widoczna w badaniu klinicznym, lecz w obrazach CBCT można dostrzec opisaną wyżej cienką warstwę kości zbitej. Ma to szczególne znaczenie u pacjentów w trakcie lub przed leczeniem ortodontycznym, gdy resorpcja tak cienkiej kości przy indukowanym ruchu zęba może doprowadzić w krótkim czasie do zaawansowanej i widocznej recesji. Analiza ta skłoniła do dalszych badań w tematyce ubytków kostnych w odcinkach uzębionych- nie tylko w aspekcie epidemiologii czy etiologii, lecz także pod kątem dalszego postępowania i przede wszystkim możliwości efektywnego leczenia.

9.2. Publikacja 2: Advancements in alveolar bone reconstruction: A systematic review of bone block utilization in dental practice.

W ostatecznej analizie uwzględniono 21 artykułów opisujących różne rodzaje bloków kostnych: autogennych, allogennych i ksenogennych, pozyskując dane od łącznie 685 pacjentów.

W publikacjach podkreślane są następujące zalety bloków autogennych: zminimalizowane ryzyko odrzucenia, dobre właściwości osteogenne, osteoindukcyjne oraz osteokondukcyjne, długotrwała stabilność oraz minimalna resorpcja. Pobranie kości autogennej niesie jednak za sobą pewne ryzyko powikłań w miejscu dawczym i dotyczy około 1/3 pacjentów.

Wymienianymi powikłaniami są: obumarcie zębów, zaburzenia neurosensoryczne, dyskomfort i ból pooperacyjny, problemy estetyczne, bliznowacenie, krwiaki, osłabienia mięśniowe, wyższe koszty hospitalizacji oraz większy stres pacjentów.

Allografty, mimo że nie posiadają właściwości osteogennych, zawierają białka morfogeniczne kości o właściwościach osteoindukcyjnych. Stwierdza się jednak, że nie jest możliwe całkowite wyeliminowanie antygenowości w przypadku tego rodzaju biomateriałów. Niemniej oznaczenie ilościowe głównych cząsteczek kompleksu zgodności tkankowej w allogennych materiałach do przeszczepów kostnych stosowanych w rekonstrukcji wyrostka zębodołowego ujawniło ich śladowe ilości- nieistotne klinicznie.

Pod względem skuteczności allogenne bloków kostnych wykazują porównywalną efektywność z blokami autogennymi, uważanymi za „złoty standard". Co więcej, allogenne przeszczepy wykazują niski współczynnik resorpcji. Ponadto względy bezpieczeństwa faworyzują alloprzeszczepy, ponieważ ich zastosowanie eliminuje ryzyko powikłań w miejscu dawczym, pozyskując materiał z banków tkanek.

Ksenografty są rzadko stosowane ze względu na wysoką immunogenność, niewystarczające właściwości biomechaniczne oraz występowanie reakcji na ciało obce, a ich skuteczność jest niższa w porównaniu do innych typów bloków.

Wśród nowoczesnych metod zwiększających efektywność zabiegów rekonstrukcyjnych z wykorzystaniem bloków kostnych wymienia się: technikę tunelową, osteotomię z wykorzystaniem lasera Er:YAG, użycie fibryny bogatopłytkowej oraz indywidualizację, która ma szczególne znaczenie, zapewniając idealne położenie i wymiary bloku. Procedura chirurgiczna z indywidualizowanymi blokami allogennymi jest prostsza, ponieważ nie wymaga modelowania i dopasowywania graftu.

Konkluzją jest, że kość autogenna nadal stanowi najlepszy biomateriał ze względu na swoje właściwości. Biorąc jednak pod uwagę potrzebę generowania drugiego pola operacyjnego, potencjalne powikłania, konieczność kształtowania oraz wydłużony czas operacji, materiały allogenne mogłyby konkurować z blokami autogennymi, jako że końcowe wyniki leczenia są bardzo często zadowalające, a nieocenioną zaletą jest możliwość ich indywidualizacji.

9.3. Publikacja 3: Possible Treatment of Severe Bone Dehiscences Based on 3D Bone Reconstruction—A Description of Treatment Methodology.

Publikacja ta miała na celu przede wszystkim przedstawienie analizowanej metody rekonstrukcji kości, wraz z charakterystyką fazy przygotowawczej oraz samego zabiegu chirurgicznego i jego efektów. Zaprezentowano przydatność diagnostyki radiologicznej w planowaniu zakresu zabiegu oraz konieczność odpowiedniego zarządzania tkankami miękkimi- przede wszystkim w zakresie dziąsła zrogowaciałego. Wykazano istotną przydatność CBCT w aspekcie projektowania wspomaganego komputerowo i następczego wytwarzania projektu (CAD/CAM), co umożliwia uzyskanie indywidualizowanego, idealnie dopasowanego do miejsca biorczego bloku kostnego. Prawidłowe ukształtowanie wszczepu w miejscu biorczym jest niezwykle ważne w procedurze rekonstrukcji, zwłaszcza pod kątem techniki zabiegowej.

Analizując kliniczny przebieg gojenia, nie stwierdzono żadnych nieprawidłowości i powikłań. Wręcz przeciwnie, odnotowano pokrycie recesji w zadowalającym stopniu oraz brak patologicznej ruchomości zębów. W kontrolnym badaniu radiologicznym po 2 latach wykazano istotny poziom odbudowy kości, wynoszący aż 6,5 mm w wymiarze pionowym. Ponadto stwierdzono obecność nowo wytworzonej warstwy kości zbitej, co jest fenomenem, z uwagi na fakt, że w zabiegu wykorzystano blok składający się jedynie z kości gąbczastej. Dowiedziono tym samym skuteczność opracowanej metody, która jednak wymaga dalszej analizy i potwierdzenia w większej grupie pacjentów.

9.4. Publikacja 4: An innovative method for three-dimensional bone reconstruction of the anterior mandible with preserved dentition using an allogeneic bone block: A 6-month follow-up.

Wykazanie znakomitego efektu rekonstrukcji kości na podstawie opisu przypadku skłoniło autorów do przeprowadzenia podobnych badań w większej grupie pacjentów (32 osoby). Zaobserwowane zmiany wymiarów kości części zębodołowej żuchwy były w większości przypadków istotne statystycznie ($p < 0,001$)- dotyczyło to strony przedsionkowej, gdzie blok kostny był umieszczany.

Im bliżej CEJ, tym większy notowano przyrost kości w wymiarze strzałkowym. Uśredniona wartości średnich dla każdego analizowanego zęba na określonych wysokościach referencyjnych wynosiła: CEJ-2: 2,9 mm, ½ CEJ-2: 2,7 mm, ¼ CEJ-2: 1,9 mm, API: 1,4 mm. Z kolei maksymalny przyrost kości w wymiarze pionowym stwierdzono przy zębie 43 (9,9 mm), następnie 32 (9,8 mm), 33 (8,5 mm), 31 (8,4 mm), 42 (8 mm), 41 (7 mm).

Nie stwierdzono istotnego wpływu wieku ani płci pacjentów na ostateczny efekt zabiegu. W znacznym odsetku pacjentów wykazano wyjściowo obecność niekorzystnych czynników, mogących mieć negatywny wpływ na efektywność rekonstrukcji kości- u ponad połowy osób cienki biotyp dziąsła i znaczne recesje dziąseł oraz u niemal połowy nadmierną aktywność mięśnia bródkowego. Nie stwierdzono jednak istotnej statystycznie różnicy pomiędzy tymi pacjentami a osobami bez powyższych czynników. Jest to niewątpliwie wynik, który zwraca szczególną uwagę na właściwe przygotowanie pacjenta, polegające nie tylko na precyzyjnym zaprojektowaniu przeszczepu, lecz także postępowaniu zgodnie z przyjętym algorytmem oraz eliminacji składowych, które mogą pogorszyć finalny rezultat.

O idealnym efekcie terapeutycznym świadczy klasa ADI w dokonanej przez nas modyfikacji Yang i wsp. Efekt ten uzyskano u 24 (75%) pacjentów. U pozostałych pacjentów nie osiągnięto ostatecznie klasy ADI, ale efekt terapeutyczny był zadowalający.

10. WNIOSKI

1) Problem częstości występowania ubytków kostnych w przednim odcinku uzębionej żuchwy, występujący u znacznej części społeczeństwa, wymaga opracowania określonych algorytmów diagnostycznych i terapeutycznych, zwłaszcza u pacjentów przed oraz w trakcie leczenia ortodontycznego.

2) Adekwatna diagnostyka kliniczna i radiologiczna (CBCT) pozwala na właściwą kwalifikację pacjenta do przewidywanego zabiegu trójwymiarowej rekonstrukcji kości, zaplanowanie jego zakresu oraz przygotowanie przeszczepu z wykorzystaniem technologii CAD/CAM.

3) Rekonstrukcja kości z użyciem allogennego, indywidualizowanego bloku kości gąbczastej w technologii 3D pozwala na osiągnięcie optymalnego efektu, włącznie z wytworzeniem nowej warstwy kości zbitej, co świadczy o znakomitej adaptacji funkcjonalnej przeszczepu.

4) Zabieg operacyjny rekonstrukcji kości jest znacznie szybszy i bardziej przewidywalny w przypadku użycia zindywidualizowanych bloków kostnych, które idealnie pasują do miejsca biorczego.

5) Przy zabiegach regeneracyjnych kości kluczowe jest odpowiednie zarządzanie tkankami miękkimi- zwłaszcza dziąsłem zrogowaciałym- oraz eliminacja niekorzystnych czynników, mogących negatywnie wpłynąć na finalny efekt, takich jak nadmierne napięcie mięśni bródkowych i inne parafunkcje.

6) Opisana i analizowana metoda jest jedyną przewidywalną i skuteczną w kontekście wertykalnej regeneracji kości w odcinkach z obecnym uzębieniem.

11. PIŚMIENNICTWO

1. Imber JC, Kasaj A. Treatment of Gingival Recession: When and How?. *Int Dent J*. 2021;71(3):178-187. doi:10.1111/idj.12617.

2. Mythri S, Arunkumar SM, Hegde S, Rajesh SK, Munaz M, Ashwin D. Etiology and occurrence of gingival recession - An epidemiological study. *J Indian Soc Periodontol*. 2015;19(6):671-675. doi:10.4103/0972-124X.156881.

3. Chan HL, Chun YH, MacEachern M, Oates TW. Does Gingival Recession Require Surgical Treatment?. *Dent Clin North Am*. 2015;59(4):981-996. doi:10.1016/j.cden.2015.06.010.

4. Mostafa D, Fatima N. Gingival Recession And Root Coverage Up To Date, A literature Review. *Dent. Rev*. 2021;2.100008. doi:10.1016/j.dentre.2021.100008.

5. Shkreta M, Atanasovska-Stojanovska A, Dollaku B, Belazelkoska Z. Exploring the Gingival Recession Surgical Treatment Modalities: A Literature Review. *Open Access Maced J Med Sci*. 2018;6(4):698-708. doi:10.3889/oamjms.2018.185.

6. Jati AS, Furquim LZ, Consolaro A. Gingival recession: its causes and types, and the importance of orthodontic treatment. *Dental Press J Orthod*. 2016;21(3):18-29. doi:10.1590/2177-6709.21.3.018-029.oin.

7. Wang M, Zhang X, Li Y, Mo A. The Influence of Different Guided Bone Regeneration Procedures on the Contour of Bone Graft after Wound Closure: A Retrospective Cohort Study. *Materials*. 2021; 14(3):583. doi.org/10.3390/ma14030583

8. Papapanou PN, Tonetti MS. Diagnosis and epidemiology of periodontal osseous lesions. *Periodontol 2000*. 2000;22:8-21. doi:10.1034/j.1600-0757.2000.2220102.x

9. Nibali L, Sultan D, Arena C, Pelekos G, Lin GH, Tonetti M. Periodontal infrabony defects: Systematic review of healing by defect morphology following regenerative surgery. *J Clin Periodontol*. 2021;48(1):100-113. doi:10.1111/jcpe.13381

10. Urban IA, Montero E, Amerio E, Palombo D, Monje A. Techniques on vertical ridge augmentation: Indications and effectiveness. *Periodontol 2000*. 2023;93(1):153-182. doi:10.1111/prd.12471

11. Blume O, Donkiewicz P, Back M, Born T. Bilateral maxillary augmentation using CAD/CAM manufactured allogenic bone blocks for restoration of congenitally missing teeth: A case report. *J Esthet Restor Dent*. 2019;31(3):171-178. doi:10.1111/jerd.12454.

12. Chaushu G, Mardinger O, Peleg M, Ghelfan O, Nissan J. Analysis of complications following augmentation with cancellous block allografts. *J Periodontol*. 2010;81(12):1759-1764. doi:10.1902/jop.2010.100235.
13. Rasperini G, Pilipchuk SP, Flanagan CL, et al. 3D-printed Bioresorbable Scaffold for Periodontal Repair. *J Dent Res*. 2015;94(9 Suppl):153-157. doi:10.1177/0022034515588303.
14. Yang Y, Yang H, Pan H, et al. Evaluation and new classification of alveolar bone dehiscences using cone-beam computed tomography *in vivo. Int. J. Morphol., 33(1)*:361-368, 2015. doi:10.4067/S0717-95022015000100057.

12. SPIS RYCIN

Publikacja 1

Rycina 1- str. 19
Rycina 2- str. 20
Rycina 3- str. 20
Rycina 4- str. 20
Rycina 5- str. 21
Rycina 6- str. 21
Rycina 7- str. 21
Rycina 8- str. 21

Publikacja 2

Rycina 1- str. 27
Rycina 2- str. 28

Publikacja 3

Rycina 1- str. 36
Rycina 2- str. 36
Rycina 3- str. 37
Rycina 4- str. 38
Rycina 5- str. 40
Rycina 6- str. 40
Rycina 7- str. 41
Rycina 8- str. 41
Rycina 9- str. 42
Rycina 10- str. 43
Rycina 11- str. 43
Rycina 12- str. 44
Rycina 13 (a,b)- str. 44,45

Publikacja 4

Rycina 1- str. 52
Rycina 2- str. 52
Rycina 3- str. 53
Rycina 4- str. 53
Rycina 5 (a,b)- str. 54
Rycina 6 (a-e)- str. 55
Rycina 7 (a,b)- str. 56
Rycina 8 (a,b)- str. 56
Rycina 9- str. 59

13. SPIS TABEL

Publikacja 1

Tabela 1- str. 20

Tabela 2- str. 21

Tabela 3- str. 22

Publikacja 2

Tabela 1- str. 27

Publikacja 4

Tabela 1- str. 53

Tabela 2- str. 57

Tabela 3- str. 58

14. ZAŁĄCZNIKI

14.1 Zgody Komisji Bioetycznej

1

KOMISJA BIOETYCZNA
przy
Uniwersytecie Medycznym
we Wrocławiu
ul. Pasteura 1; 50-367 WROCŁAW

OPINIA KOMISJI BIOETYCZNEJ Nr KB – 530/2021

Komisja Bioetyczna przy Uniwersytecie Medycznym we Wrocławiu, powołana zarządzeniem Rektora Uniwersytetu Medycznego we Wrocławiu nr 278/XVI R/2020 z dnia 21 grudnia 2020 r. oraz działająca w trybie przewidzianym rozporządzeniem Ministra Zdrowia i Opieki Społecznej z dnia 11 maja 1999 r. (Dz.U. nr 47, poz. 480) na podstawie ustawy o zawodzie lekarza z dnia 5 grudnia 1996 r. (Dz.U. nr 514 z 2020 r.) w składzie:

dr Joanna Birecka (psychiatria)

dr Beata Freier (onkologia)

dr hab. Tomasz Fuchs (ginekologia, położnictwo)

prof. dr hab. Dariusz Janczak (chirurgia naczyniowa, transplantologia)

dr hab. Krzysztof Kaliszewski (chirurgia endokrynologiczna)

dr prawa Andrzej Malicki (prawo)

dr hab. Marcin Mączyński (farmacja)

Urszula Olechowska (pielęgniarstwo)

prof. dr hab. Leszek Szenborn (pediatria, choroby zakaźne)

prof. dr hab. Andrzej Szuba (choroby wewnętrzne, angiologia

ks. prof. Andrzej Tomko (duchowny)

prof. dr hab. Mieszko Więckiewicz (stomatologia)

dr hab. Andrzej Wojnar, prof. nadzw. (histopatologia, dermatologia) przedstawiciel Dolnośląskiej Izby Lekarskiej)

dr hab. Jacek Zieliński (filozofia)

pod przewodnictwem
prof. dr hab. Jerzego Rudnickiego (chirurgia, proktologia)

Przestrzegając w działalności zasad Good Clinical Practice oraz zasad Deklaracji Helsińskiej, po zapoznaniu się z wnioskiem zgłoszonym przez **lek. dent.Sebastiana Dominiaka,** pracownika Katedry i Zakładu Chirurgii Stomatologicznej Uniwersytetu Medycznego we Wrocławiu do projektu badawczego pt.:

„Ocena stabilności ubytków kostnych w łukach uzębionych indywidualizowanym blokiem kostnym 3D "

w tajnym głosowaniu postanowiła wyrazić zgodę na przeprowadzenie badania w Katedrze i Zakładzie Chirurgii Stomatologicznej Uniwersytetu Medycznego we Wrocławiu, SCTT Sp. z o. o. Specjalistycznej Poradni Chirurgii Stomatologicznej we Wrocławiu i Duo-Med we Wrocławiu **pod warunkiem zachowania anonimowości uzyskanych danych**.
Badanie będzie prowadzone pod nadzorem prof. dr hab. Tomasza Gedrange i promotora pomocniczego dr Pawła Kubasiewicza-Rossa

Uwaga: Badanie to zostało objęte ubezpieczeniem odpowiedzialności cywilnej Uniwersytetu Medycznego we Wrocławiu z tytułu prowadzonej działalności.

Pouczenie: W ciągu 14 dni od otrzymania decyzji wnioskodawcy przysługuje prawo odwołania do Komisji Odwoławczej za pośrednictwem Komisji Bioetycznej UM we Wrocławiu.

Opinia powyższa dotyczy projektu badawczego będącego podstawą rozprawy doktorskiej.

Przewodniczący Komisji Bioetycznej
przy Uniwersytecie Medycznym

prof. dr hab. Jerzy Rudnicki

Wrocław, dnia 8 czerwca 2021 r.

Uniwersytet Medyczny
im. Piastów Śląskich we Wrocławiu

Komisja Bioetyczna przy Uniwersytecie Medycznym
ul. Mikulicza-Radeckiego 4a, 50-367 Wrocław
bioetyka@umw.edu.pl
https://www.umw.edu.pl/pl/komisja-bioetyczna

UCHWAŁA KOMISJI BIOETYCZNEJ Nr KB 284/2023N

z dnia 23 listopada 2023r., w sprawie
wyrażenia opinii o projekcie badania medycznego, pn.:

„Ocena efektywności nowej metody rekonstrukcji kości żuchwy z wykorzystaniem indywidualizowanego 3D allogennego bloku kostnego w odcinkach uzębionych", lek. dent. Sylwia Hnitecka

Komisja Bioetyczna przy Uniwersytecie Medycznym we Wrocławiu powołana Zarządzeniem nr 68/XVI R/2023 Rektora Uniwersytetu Medycznego we Wrocławiu z dnia 26 kwietnia 2023 r. od dnia 1 maja 2023 na kadencję 2023-2026 oraz działająca w trybie przewidzianym Rozporządzeniem Ministra Zdrowia z dnia 26 stycznia 2023 r. w sprawie komisji bioetycznej oraz Odwoławczej Komisji Bioetycznej (Dz. U. z 2023 r. poz. 218.), wydanym na podstawie art. 29 ust. 26 ustawy z dnia 5 grudnia 1996 r. o zawodach lekarza i lekarza dentysty (Dz. U. z 2022 r. poz. 1731, 1733, 2731 i 2770), na posiedzeniu w dniu **23 listopada 2023 roku, w składzie**:

prof. dr hab. Dariusz JANCZAK (chirurgia naczyniowa, transplantologia kliniczna)
prof. dr hab. Leszek SZENBORN (pediatria, choroby zakaźne)
prof. dr hab. Rafał MATKOWSKI (chirurgia onkologia)
prof. dr hab. Błażej MISIAK (psychiatria)
prof. dr hab. Marzenna PODHORSKA-OKOŁÓW (okulistyka, biologia medyczna)
prof. dr hab. Mieszko WIĘCKIEWICZ (stomatologia)
prof. dr hab. Tomasz WRÓBEL (hematologia)
dr hab. Katarzyna MADZIARSKA, prof. Uczelni (nefrologia)
dr hab. Marcin MĄCZYŃSKI, prof. Uczelni (farmacja)
dr hab. Marcin PROTASIEWICZ, prof. Uczelni (kardiologia)
dr hab. Tomasz JUREK, prof. Uczelni (medycyna sądowa)
dr hab. Andrzej WOJNAR, prof. Uczelni (histopatologia, dermatologia, przedstawiciel DIL)
dr hab. Jacek ZIELIŃSKI (filozofia)
mgr Lidia ŻOŁĘDZIOWSKA (prawo)

pod przewodnictwem dr hab. Tomasza Jurka, prof. Uczelni, **przestrzegając zasad** Good Clinical Practice, zasad Deklaracji Helsińskiej, oraz zgodnie z przepisami prawa powszechnie obowiązującymi w zakresie wydawania ocen etycznych eksperymentów medycznych, a także po zapoznaniu się z:

1. projektem badania medycznego pn.: „Ocena efektywności nowej metody rekonstrukcji kości żuchwy z wykorzystaniem indywidualizowanego 3D allogennego bloku kostnego w odcinkach uzębionych", **zgłoszonym przez lek. dent. Sylwię Hnitecką**, zatrudnionej w Katedrze i Klinice Chirurgii Szczękowo-Twarzowej **Uniwersytetu Medycznego we Wrocławiu,**

Komisja Bioetyczna przy Uniwersytecie Medycznym
ul. Mikulicza-Radeckiego 4a, 50-367 Wrocław
bioetyka@umw.edu.pl
https://www.umw.edu.pl/pl/komisja-bioetyczna

2. projektem opinii o badaniu medycznym pn.: „Ocena efektywności nowej metody rekonstrukcji kości żuchwy z wykorzystaniem indywidualizowanego 3D allogennego bloku kostnego w odcinkach uzębionych", **sporządzonym przez Prof. dr. hab. Mieszka Więckiewicza,** zgodnie z wymaganiami par. 7 ust. 3 Rozporządzenia Ministra Zdrowia z dnia 26 stycznia 2023r, w sprawie komisji bioetycznej oraz Odwoławczej Komisji Bioetycznej (Dz. U. z 2023 r. poz. 218) oraz ze złożonymi wraz z wnioskiem dokumentami,

po przeprowadzeniu tajnego głosowania postanowiła **wyrazić pozytywną opinię** o ww. projekcie badania medycznego,

Pouczenie: W terminie 14 dni od otrzymania niniejszej opinii Wnioskodawcy przysługuje prawo odwołania do Komisji Odwoławczej za pośrednictwem Komisji Bioetycznej przy UM we Wrocławiu.

Niniejsza Uchwała dotyczy projektu będącego podstawą pracy doktorskiej.

Przewodniczący Komisji Bioetycznej
przy Uniwersytecie Medycznym

dr hab. Tomasz Jurek, prof. Uczelni

Wrocław, dnia 23 listopada 2023 r.

14.2. Dorobek naukowy doktoranta

Polska Platforma Medyczna

Raport dorobku z dnia 13-08-2024

lek. dent. Sylwia Hnitecka

asystent

Katedra i Klinika Chirurgii Szczękowo-Twarzowej

Wydział Lekarsko-Stomatologiczny

ORCID: 0000-0002-1171-9817

Punktacja za publikacje:

	Liczba	IF	Punkty
1.1 Publikacje w czasopiśmie z IF	12	36,786	980
1.2 Publikacje w czasopiśmie bez IF	14		81
1.3 Publikacje w czasopiśmie - prace kontrybutorskie	0	0	0
2.1 Książka autorska	0		0
2.2 Książka redagowana	0		0
2.3 Rozdziały *	1		20
			1081

** Punktacja za rozdziały wymaga ręcznego sprawdzenia - liczba punktów za autorstwo albo współautorstwo rozdziałów w jednej monografii /podręczniku nie może być większa niż całkowita wartość punktowa monografii/podręcznika wg punktacji obowiązującej w danym roku (patrz tabela) .*

1. Publikacje w czasopismach naukowych

1.1 Publikacje w czasopiśmie z IF

Lp.	Opis bibliograficzny	Rok	IF	Punkty	Kategoria
1	Rutkowska Monika, Hnitecka Sylwia, Nahajowski Marek, Dominiak Marzena, Gerber Hanna: Oral cancer: the first symptoms and reasons for delaying correct diagnosis and appropriate treatment, Advances in Clinical and Experimental Medicine, 2020, vol. 29, nr 6, s. 735-743, DOI:10.17219/acem/116753	2020	1,727	70	praca oryginalna
2	Więckiewicz Mieszko, Grychowska Natalia, Nahajowski Marek, Hnitecka Sylwia, Kempiak Karolina, Charemska Karolina, Balicz Agnieszka, Chirkowska Anna, Ziętek Marek, Winocur Efraim: Prevalence and overlaps of headaches and pain-related temporomandibular disorders among the Polish urban population, Journal of oral & facial pain and headache, 2020, vol. 34, nr 1, s. 31-39, DOI:10.11607/ofph.2386	2020	1,871	100	praca oryginalna

3	Olchowy Cyprian, Więckiewicz Mieszko, Sconfienza Luca Maria, Łasecki Mateusz, Seweryn Piotr, Smardz Joanna, Hnitecka Sylwia, Dominiak Marzena, Olchowy Anna: Potential of using shear wave elastography in the clinical evaluation and monitoring of changes in masseter muscle stiffness, Pain Research & Management, 2020, vol. 2020, art.4184268 [5 s.], DOI:10.1155/2020/4184268	2020	3,037	70	praca oryginalna
4	Woźniak Marta, Nahajowski Marek, Hnitecka Sylwia, Rutkowska Monika, Marek Grzegorz, Agrawal Anil Kumar, Makuch Sebastian, Agrawal Siddarth, Ziółkowski Piotr: A comparative study of osteopontin expression, Ki67 index and prognosis in squamous cell carcinoma and cysts of the oral cavity, Translational Cancer Research, 2020, vol. 9, nr 2, s. 795-808, DOI:10.21037/tcr. 2019.12.08	2020	1,241	40	praca oryginalna
5	Dominiak Marzena, Hnitecka Sylwia, Olchowy Cyprian, Olchowy Anna, Gedrange Tomasz: Analysis of alveolar ridge width in an area of central lower incisor using cone-beam computed tomography in vivo, Annals of Anatomy-Anatomischer Anzeiger, 2021, vol. 236, art.151699 [7 s.], DOI:10.1016/j.aanat.2021.151699	2021	2,976	100	praca oryginalna
6	Dominiak Marzena, Hnitecka Sylwia, Olchowy Cyprian, Dominiak Sebastian, Gedrange Tomasz: Possible treatment of severe bone dehiscences based on 3D bone reconstruction - a description of treatment methodology, Applied Sciences-Basel, 2021, vol. 11, nr 21, art.10299 [16 s.], DOI:10.3390/app112110299	2021	2,838	100	praca kazuistyczna
7	Nahajowski Marek, Hnitecka Sylwia, Antoszewska-Smith Joanna, Rumin Kornelia, Dubowik Magdalena, Sarul Michał: Factors influencing an eruption of teeth associated with a dentigerous cyst: a systematic review and meta-analysis, BMC Oral Health, 2021, vol. 21, art.180 [11 s.], DOI:10.1186/s12903-021-01542-y	2021	3,747	100	praca oryginalna
8	Woźniak Marta, Nahajowski Marek, Hnitecka Sylwia, Rutkowska Monika, Nowak Martyna, Mitelsztet Patryk, Szkudlarek Danuta, Makuch Sebastian: Expression of syndecan-1 in oral cavity squamous cell carcinoma, Journal of Histotechnology, 2021, vol. 44, nr 1, s. 46-51, DOI:10.1080/01478885.2020.1861918	2021	1,918	20	praca oryginalna
9	Leszczyszyn Anna, Hnitecka Sylwia, Dominiak Marzena: Could vitamin D3 deficiency influence malocclusion development?, Nutrients, 2021, vol. 13, nr 6, art.2122 [10 s.], DOI:10.3390 /nu13062122	2021	6,706	140	praca oryginalna
10	Michalak Filip, Hnitecka Sylwia, Dominiak Marzena, Grzech-Leśniak Kinga: Schemes for drug-induced treatment of osteonecrosis of jaws with particular emphasis on the influence of vitamin D on therapeutic effects, Pharmaceutics, 2021, vol. 13, nr 3, art.354 [13 s.], DOI:10.3390/pharmaceutics13030354	2021	6,525	100	praca przeglądowa
11	Gerber Hanna, Gedrange Tomasz, Szymor Piotr, Leszczyszyn Anna, Kubiak Marcin, Rutkowska Monika, Sarul Michał, Hnitecka Sylwia: Oral cancer awareness among patients at 3 university hospitals in Poland and Germany: a survey research, Advances in Clinical and Experimental Medicine, 2022, vol. 31, nr 6, s. 607-613, DOI:10.17219/acem/146455	2022	2,1	70	praca oryginalna
12	Dominiak Marzena, Leszczyszyn Anna, Łaczmańska Izabela, Machoy Monika, Gerber Hanna, Choukroun Joseph, Gedrange Tomasz, Hnitecka Sylwia: Relationship in development of malocclusions to polymorphisms of selected vitamin D receptors, Advances in Clinical and Experimental Medicine, 2024, vol. 33, nr 6, s. 601-608, DOI:10.17219/acem/169977	2024	2,1	70	praca oryginalna
	Podsumowanie		36,786	980	

1.2 Publikacje w czasopiśmie bez IF

Lp.	Opis bibliograficzny	Rok	Punkty	Kategoria

1	Hnitecka Sylwia, Nahajowski Marek, Komorski Józef Andrzej, Nelke Kamil: Leczenie ortognatyczne z perspektywy pacjenta - badanie ankietowe, Dental and Medical Problems, 2016, vol. 53, nr 1, s. 89-102, DOI:10.17219/dmp /60138	2016	11	praca oryginalna
2	Hnitecka Sylwia, Nelke Kamil: Rhinocerebral mucormycosis: clinical outcome, diagnosis, treatment - review of the literature, Dental and Medical Problems, 2016, vol. 53, nr 4, s. 536-541, DOI:10.17219/dmp/64144	2016	11	praca przeglądowa
3	Rutkowska Monika, Hnitecka Sylwia, Nelke Kamil: Rynolit w dolnym przewodzie nosowym - opis przypadku, Otolaryngologia - Przegląd kliniczny, 2016, vol. 15, nr 2, s. 107-109	2016	8	praca kazuistyczna
4	Hnitecka Sylwia, Nelke Kamil: Syndromiczny zespół cichej zatoki - postępowanie i wyniki leczenia u pacjenta ze szkieletową wadą zębowo-twarzową 1,2, Polski Przegląd Otorynolaryngologiczny, 2016, vol. 5, nr 3, s. 43-48, DOI:10.5604/20845308.1219924	2016	7	
5	Hadzik Jakub, Leszczyszyn Anna, Hnitecka Sylwia, Dominiak Marzena: Autogenne sposoby postępowania i/lub regeneracji zębodołu po utracie zęba stałego, Implants. International magazine of oral implantology, 2017, vol. 12, nr 2, s. 6-16	2017	6	praca przeglądowa
6	Hnitecka Sylwia, Hadzik Jakub, Smulczyńska-Demel Anna, Szulc Małgorzata, Dominiak Marzena: Możliwości wykorzystania mielonego zęba jako materiału augmentacyjnego w chirurgii regeneracyjnej wyrostka zębodołowego - opis przypadków, Implants. International magazine of oral implantology, 2017, vol. 12, nr 4, s. 14-23	2017	6	praca kazuistyczna
7	Nahajowski Marek, Hnitecka Sylwia, Gorzel Patrycja, Majchrzak Anna, Skośkiewicz-Malinowska Katarzyna, Malicka Barbara: Analiza częstości występowania kserostomii u osób w podeszłym wieku, Magazyn Stomatologiczny, 2017, vol. 27, nr 10, s. 64-68	2017	6	praca oryginalna
8	Dominiak Marzena, Hnitecka Sylwia: Śródzabiegowa ocena jakościowo-ilościowa flory bakteryjnej patologicznych kieszonek dziąsłowych leczonych z wykorzystaniem lasera Er:YAG i Nd:YAG - opis przypadku = Intraprocedural evaluation of the quality and quantity of bacterial flora in pathological periodontal pockets treated using Er:YAG lasers - case report, e-Dentico Dwumiesięcznik Stomatologa Praktyka, 2017, nr 1, s. 154-162	2017	6	praca kazuistyczna
9	Hnitecka Sylwia, Hadzik Jakub, Smulczyńska-Demel Anna, Szulc Małgorzata, Dominiak Marzena: Możliwości wykorzystania materiałów augmentacyjnych oraz laserów Er:YAG i Nd:YAG w chirurgii regeneracyjnej wyrostka zębodołowego - opis przypadków, Laser. International Magazine of Laser Dentistry (Wyd. polskie), 2018, vol. 5, nr 2, s. 24-32	2018	0	praca kazuistyczna
10	Hnitecka Sylwia, Dominiak Marzena: Zastosowanie laserowej metody TwinLight w leczeniu periimplantitis - opis przypadku, Laser. International Magazine of Laser Dentistry (Wyd. polskie), 2018, vol. 5, nr 2, s. 6-16	2018	0	praca kazuistyczna
11	Hnitecka Sylwia, Dominiak Marzena: Torbiel samotna okolicy pośrodkowej trzonu żuchwy - obraz kliniczny i leczenie. Opis przypadku, Magazyn Stomatologiczny, 2019, vol. 29, nr 5, s. 36-40, [Publikacja w czasopiśmie spoza listy MNiSW]	2019	5	praca kazuistyczna
12	Nahajowski Marek, Majchrzak Anna, Hnitecka Sylwia, Gorzel Patrycja, Malicka Barbara, Skośkiewicz-Malinowska Katarzyna: Ocena częstości występowania suchości jamy ustnej i objawów depresji u osób w podeszłym wieku, TPS-Twój Przegląd Stomatologiczny, 2019, nr 4, s. 81-86, [Publikacja w czasopiśmie spoza listy MNiSW]	2019	5	praca oryginalna
13	Wiecha Anna, Hnitecka Sylwia, Sadowski Roman: Przerzut raka nerkowokomórkowego (RCC) do żuchwy – opis przypadku, TPS-Twój Przegląd Stomatologiczny, 2021, nr 7-8, s. 64-66, [Publikacja w czasopiśmie spoza listy MNiSW]	2021	5	praca kazuistyczna

14	Pastor Sławomir, Hnitecka Sylwia, Kowalska Agnieszka, Bijak Karol: Rehabilitacja protetyczna pacjenta z resztkowym uzębieniem w żuchwie z zastosowaniem implantów zębowych z natychmiastowym obciążeniem w pełnym protokole cyfrowym. Opis przypadku, Implantologia Stomatologiczna, 2022, vol. 12, nr 2, 42-51, 53, [Publikacja w czasopiśmie spoza listy MNiSW]	2022	5	praca kazuistyczna
	Podsumowanie		81	

1.3 Publikacje w czasopiśmie - prace kontrybutorskie

brak publikacji

2. Monografie naukowe

2.1 Książka autorska

brak publikacji

2.2 Książka redagowana

brak publikacji

2.3 Rozdziały

Lp.	Opis bibliograficzny	Rok	Punkty	Kategoria
1	Rutkowska Monika, Hnitecka Sylwia, Dominiak Marzena: Sinonasal malignancies - clinicopathological characteristics and difficulties in diagnostics, W: Advances in biomedical research : from cancer prevention to treatment, (red.) Izabela Młynarczuk-Biały, Łukasz Biały, Lublin ; Warszawa 2020, Warszawski Uniwersytet Medyczny, s. 143-156, ISBN 978-83-66489-45-5, 978-83-7637-551-9	2020	20	
	Podsumowanie		20	

3. Varia

3.1 Komentarz

brak publikacji

3.2 Inne

brak publikacji

4. Abstrakty

Lp.	Opis bibliograficzny	Rok
1	Krawiec Maciej, Hadzik Jakub, Hnitecka Sylwia, Dominiak Marzena: 6 mm and 8 mm dental implants in mandible - 12 months follow-up, International Dental Journal, 2017, vol. 67, nr suppl.1, 37-38 poz. P023, [105th FDI Annual World Dental Congress. Madrid (Spain), 29 August - 1 September 2017. Abstracts]	2017
2	Więckiewicz Mieszko, Nahajowski Marek, Hnitecka Sylwia, Kempiak Karolina, Charemska Karolina, Balicz Agnieszka, Chirkowska Anna, Ziętek Marek, Grychowska Natalia: Rozpowszechnienie postaci bólowej dysfunkcji narządu żucia oraz bólu głowy w populacji polskiej. Badanie pilotażowe, Protetyka Stomatologiczna, 2018, vol. 68, nr 2, 154-155 poz.R9, [XXXV Konferencja Naukowo-Szkoleniowa Sekcji Protetyki PTS. Supraśl, 7-9 czerwca 2018]	2018

3	Nienartowicz Jan, Hnitecka Sylwia, Tomczyk-Kurza Katarzyna: Stany zapalne twarzy i szyi - analiza retrospektywna 100 pacjentów = Inflammation of the face and neck - retrospective analysis of 100 patients, W: Kongres Polskiego Towarzystwa Chirurgii Stomatologicznej i Szczękowo-Twarzowej. Lublin, 16-18 września 2021 2021, s. 111-112	2021
4	Michalak Filip, Hnitecka Sylwia, Dominiak Marzena: Surgical treatment ofmedication-related osteonecrosis of thejaw (MRONJ) with the use ofEr:YAG laser, Advances in Clinical and Experimental Medicine, 2023, vol. 32, nr 4 spec., s. 217, [17th Congress of the World Federation for Laser Dentistry. Wrocław, Poland, April 14-16, 2023. Abstract book]	2023
5	Michalak Filip, Hnitecka Sylwia, Dominiak Marzena: Surgical treatment of medication-related osteonecrosis of the jaw (MRONJ) with the use of Er:YAG laser, W: The 17th Congress of the World Federation for Laser Dentistry "Laser in health science". Wroclaw, 14–16.04.2023. Abstract book [online] 2023, 139-140 poz.P-56	2023

14.3. Oświadczenia współautorów

Lek. dent. Sylwia Hnitecka
Katedra i Zakład Chirurgii Stomatologicznej
Uniwersytet Medyczny we Wrocławiu

Wrocław, 13.08.2024

OŚWIADCZENIE

Oświadczam, że w pracach:

1. Dominiak M, **Hnitecka S**, Olchowy C, Olchowy A, Gedrange T. Analysis of alveolar ridge width in an area of central lower incisor using cone-beam computed tomography in vivo. *Ann Anat*. 2021;236:151699.
2. **Hnitecka S**, Olchowy C, Olchowy A, Dąbrowski P, Dominiak M. Advancements in alveolar bone reconstruction: A systematic review of bone block utilization in dental practice. *Dent Med Probl*. Published online May 23, 2024. doi:10.17219/dmp/181532
3. Dominiak M, **Hnitecka S**, Olchowy C, Dominiak S, Gedrange T. Possible Treatment of Severe Bone Dehiscences Based on 3D Bone Reconstruction—A Description of Treatment Methodology. *Applied Sciences*. 2021; 11(21):10299.
4. **Hnitecka S**, Dominiak M, Olchowy C, Gedrange T. An innovative method for three-dimensional bone reconstruction of the anterior mandible with preserved dentition using an allogeneic bone block: A 6-month follow-up. *Adv Clin Exp Med*. Published online August 9, 2024. doi:10.17219/acem/189840

mój udział polegał na: formułowaniu hipotez i problemów badawczych oraz stworzeniu koncepcji pracy i projektowaniu badań (publikacja 1,2,3,4), gromadzeniu i analizie danych (publikacja 1,2,3,4), interpretacji wyników (publikacja 1,2,3,4), przygotowaniu i korekcie manuskryptów (publikacja 1,2,3,4).

Podpis

Prof. dr hab. n. med. Marzena Dominiak
Katedra i Zakład Chirurgii Stomatologicznej
Uniwersytet Medyczny we Wrocławiu

Wrocław, 13.08.2024

OŚWIADCZENIE

Oświadczam, że w pracach:

1. **Dominiak M**, Hnitecka S, Olchowy C, Olchowy A, Gedrange T. Analysis of alveolar ridge width in an area of central lower incisor using cone-beam computed tomography in vivo. *Ann Anat*. 2021;236:151699.
2. Hnitecka S, Olchowy C, Olchowy A, Dąbrowski P, **Dominiak M**. Advancements in alveolar bone reconstruction: A systematic review of bone block utilization in dental practice. *Dent Med Probl*. Published online May 23, 2024. doi:10.17219/dmp/181532
3. **Dominiak M**, Hnitecka S, Olchowy C, Dominiak S, Gedrange T. Possible Treatment of Severe Bone Dehiscences Based on 3D Bone Reconstruction—A Description of Treatment Methodology. *Applied Sciences*. 2021; 11(21):10299.
4. Hnitecka S, **Dominiak M**, Olchowy C, Gedrange T. An innovative method for three-dimensional bone reconstruction of the anterior mandible with preserved dentition using an allogeneic bone block: A 6-month follow-up. *Adv Clin Exp Med*. Published online August 9, 2024. doi:10.17219/acem/189840

mój udział polegał na: formułowaniu hipotez i problemów badawczych oraz stworzeniu koncepcji pracy (publikacja 1,2,3,4), interpretacji wyników (publikacja 1,3), przygotowaniu manuskryptów (publikacja 3), korekcie manuskryptów (publikacja 1,2,3,4)

Podpis

Signed by /
Podpisano przez:
Marzena
Dominiak
Date / Data:
2024-08-14 10:22

Dr hab. n. med. Cyprian Olchowy, prof. UJD
Katedra Kliniczna Chorób Układu Krążenia
Uniwersytet Jana Długosza w Częstochowie

Wrocław, 13.08.2024

OŚWIADCZENIE

Oświadczam, że w pracach:

1. Dominiak M, Hnitecka S, **Olchowy C**, Olchowy A, Gedrange T. Analysis of alveolar ridge width in an area of central lower incisor using cone-beam computed tomography in vivo. *Ann Anat*. 2021;236:151699.
2. Hnitecka S, **Olchowy C**, Olchowy A, Dąbrowski P, Dominiak M. Advancements in alveolar bone reconstruction: A systematic review of bone block utilization in dental practice. *Dent Med Probl*. Published online May 23, 2024. doi:10.17219/dmp/181532
3. Dominiak M, Hnitecka S, **Olchowy C**, Dominiak S, Gedrange T. Possible Treatment of Severe Bone Dehiscences Based on 3D Bone Reconstruction—A Description of Treatment Methodology. *Applied Sciences*. 2021; 11(21):10299.
4. Hnitecka S, Dominiak M, **Olchowy C**, Gedrange T. An innovative method for three-dimensional bone reconstruction of the anterior mandible with preserved dentition using an allogeneic bone block: A 6-month follow-up. *Adv Clin Exp Med*. Published online August 9, 2024. doi:10.17219/acem/189840

mój udział polegał na: stworzeniu koncepcji pracy (publikacja 2,4), interpretacji wyników (publikacja 1,3), przygotowaniu i korekcie manuskryptów (publikacja 1,2,3,4)

Podpis

C. Olchowy

Prof. dr hab. n. med. Tomasz Gedrange
Katedra i Zakład Chirurgii Stomatologicznej
Uniwersytet Medyczny we Wrocławiu

Wrocław, 13.08.2024

OŚWIADCZENIE

Oświadczam, że w pracach:

1. Dominiak M, Hnitecka S, Olchowy C, Olchowy A, **Gedrange T**. Analysis of alveolar ridge width in an area of central lower incisor using cone-beam computed tomography in vivo. *Ann Anat*. 2021;236:151699.
2. Dominiak M, Hnitecka S, Olchowy C, Dominiak S, **Gedrange T**. Possible Treatment of Severe Bone Dehiscences Based on 3D Bone Reconstruction—A Description of Treatment Methodology. *Applied Sciences*. 2021; 11(21):10299.
3. Hnitecka S, Dominiak M, Olchowy C, **Gedrange T**. An innovative method for three-dimensional bone reconstruction of the anterior mandible with preserved dentition using an allogeneic bone block: A 6-month follow-up. *Adv Clin Exp Med*. Published online August 9, 2024. doi:10.17219/acem/189840

mój udział polegał na: stworzeniu koncepcji pracy (publikacja 2,3), interpretacji wyników (publikacja 2), korekcie manuskryptów (publikacja 1,3)

Dental Surgery Department
of Silesian Piast Medical University
of Wrocław, Poland
prof. dr hab. Tomasz Gedrange

Podpis

Dr n. med. Anna Olchowy
Katedra i Zakład Stomatologii Doświadczalnej
Uniwersytet Medyczny we Wrocławiu

Wrocław, 13.08.2024

OŚWIADCZENIE

Oświadczam, że w pracach:

1. Dominiak M, Hnitecka S, Olchowy C, **Olchowy A**, Gedrange T. Analysis of alveolar ridge width in an area of central lower incisor using cone-beam computed tomography in vivo. *Ann Anat*. 2021;236:151699.
2. Hnitecka S, Olchowy C, **Olchowy A**, Dąbrowski P, Dominiak M. Advancements in alveolar bone reconstruction: A systematic review of bone block utilization in dental practice. *Dent Med Probl*. Published online May 23, 2024. doi:10.17219/dmp/181532

mój udział polegał na: gromadzeniu i analizie danych oraz interpretacji wyników (publikacja 1,2)

Podpis

Lek. dent. Sebastian Dominiak
Katedra i Zakład Chirurgii Stomatologicznej
Uniwersytet Medyczny we Wrocławiu

Wrocław, 13.08.2024

OŚWIADCZENIE

Oświadczam, że w pracy:

1. Dominiak M, Hnitecka S, Olchowy C, **Dominiak S**, Gedrange T. Possible Treatme[nt] of Severe Bone Dehiscences Based on 3D Bone Reconstruction—A Description of Treatment Methodology. *Applied Sciences*. 2021; 11(21):10299.

mój udział polegał na: gromadzeniu i analizie danych oraz interpretacji wyników.

Podpis

Sebastian Dominiak
LEKARZ DENTYSTA
PWZ 3559054

Dr n. biol. Paweł Dąbrowski
Zakład Anatomii Prawidłowej
Uniwersytet Medyczny we Wrocławiu

Wrocław, 13.08.2024

OŚWIADCZENIE

Oświadczam, że w pracy:

1. Hnitecka S, Olchowy C, Olchowy A, **Dąbrowski P**, Dominiak M. Advancements in alveolar bone reconstruction: A systematic review of bone block utilization in dental practice. *Dent Med Probl*. Published online May 23, 2024. doi:10.17219/dmp/181532

mój udział polegał na: gromadzeniu i analizie danych oraz interpretacji wyników.

Paweł Dąbrowski
Podpis

Uniwersytet Medyczny we Wrocławiu
Katedra Morfologii i Embriologii Człowieka
ZAKŁAD ANATOMII PRAWIDŁOWEJ
kierownik Pracowni Paleoanatomii

dr n. biol. Paweł Dąbrowski