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Long Term Comparison of Application of Two Beta-Tricalcium Phosphates in Oral Surgery

Porównanie odległych wyników leczenia z zastosowaniem dwóch beta-trójfosforanów wapnia w chirurgii jamy ustnej

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Abstract

Background. Nowadays the bone substitute materials are widely applied in the oral surgery.
Objectives. This article covers the comparison of two bone-substitute materials – ChronOS® and Cerasorb® (both pertain to beta-tricalcium phosphates group), the quality of newly created bone was compared.
Material and Methods. For the purposes of this paper, the analysis of X-ray photographs of 90 patients has been conducted. Intraoral periapical radiographs were made on the day of a surgery and 3, 6, 9, 12, 18 and 24 months after the surgery such as extraction, resection and cyst removal. The quality of the newly created bones was compared and contrasted taking into consideration sex of the patient, the kind of surgery, and location where the bone-substitute material was applied.
Results. The above-mentioned materials belong to the same group of tricalcium phosphates, but have different shape, size, and surface structure of granule, as a result of which there are slight differences on the bone regeneration activity observed during a few months post-operatively.
Conclusion. Application of beta-tricalcium phosphate bone substitute materials leads to as proper reconstruction as the reference bone structure is, independently on brand of investigated products (**Dent. Med. Probl. 2009, 46, 4, 384–388**).

Key words: bone substitute materials, beta-tricalcium phosphates.

Streszczenie

Wprowadzenie. W dzisiejszych czasach materiały kościozastępcze są szeroko stosowane w chirurgii jamy ustnej.
Cel pracy. Porównanie dwóch materiałów kościozastępczych – ChronOS® i Cerasorb® (oba z grupy β-trójfosforanów wapniowych) pod względem jakości nowo powstałej kości.
Materiał i metody. W pracy dokonano analizy zdjęć RTG wykonanych u 90 pacjentów. Zdjęcia RTG zostały zrobione w dniu zabiegu oraz po 3, 6, 9, 12, 18 i 24 miesiącach po zabiegach: ekstrakcji, resekcji lub usunięcia torbieli. Porównano również jakość powstałej kości ze względu na płeć pacjentów, rodzaj zabiegu i umiejscowienie ubytku kości, gdzie stosowano materiał kościozastępczy.
Wyniki. Materiały te należą do jednej grupy β-trójwapniowych fosforanów, różnią się jednak między sobą kształtem, wielkością i strukturą powierzchni cząstek, co wpływa na niewielkie zaobserwowane różnice w szybkości regeneracji kości w pierwszych miesiącach po zabiegach chirurgicznych.
Wnioski. Zastosowanie materiału kościozastępczego z grupy β-trójfosforanów wapniowych prowadzi do tak prawidłowej rekonstrukcji jak struktura referencyjnej kości, niezależnie od marki badanego materiału kościozastępczego (**Dent. Med. Probl. 2009, 46, 4, 384–388**).

Słowa kluczowe: materiały kościozastępcze, beta-fosforany trójwapniowe.

Autologous bone graft is still considered the "gold standard", but its supply is often limited, and harvesting of the graft has attendant morbidity [1, 2]. That is why bone substitute materials are widely applied in the oral surgery. Thanks to them there is a possibility to regenerate bone after tooth removals, apicoectomies or cyst enucleations. They are also applied in order to increase the amount of bone tissue prior to dental implant insertions.

Features of the ideal bone substitute material are as follows: biocompatibility, angiogenesis stimulation, porosity, haemostatic activity, full resorption [3]. Currently, due to the fact that there is a wide choice of bone replacement materials, the preparation that fulfills most of the above-mentioned criteria is searched for. Producers often indicate the superiority of their manufactured goods over the competitor.

In the present study, the authors discuss two bone substitute materials from beta-tricalcium phosphates: Cerasorb® and ChronOS®. Both materials are granulated with porous surface. The element composition indicates the presence of beta-tricalcium phosphate, amount of which is proportional to the bioresorption rate, which influences significantly the quality of newly built bone [4–7]. This feature enables to shorten the period of vital and functional bone creation in place of osseous defect.

Material and Methods

Two beta-tricalcium phosphates granulated biomaterials were applied into 90 patients (female: 53, male: 37). Cerasorb (Curasan, Germany, Fig. 1) of gradation 1–2 mm particles was utilized in 58 cases, and ChronOS (Synthes, USA, Fig. 2) of gradation 0.7–1.4 mm particles was put into 32 cases. Materials were implanted into bone defects after apicoectomies, impacted tooth removals and cyst enucleations (i.e. periapical surgery and intra-alveolar surgery).

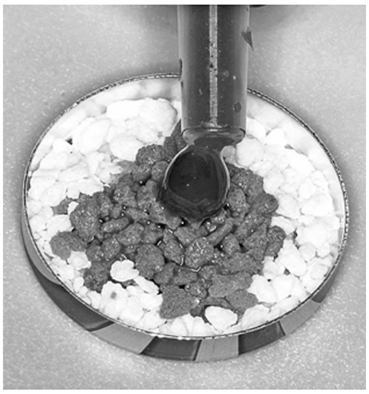

Fig. 1. Cerasorb particles with blood just before implantation. Particles are spherical and hydrophylic

Ryc. 1. Cząstki Cerasorb z krwią tuż przed zabiegiem. Cząstki są kuliste i hydrofilne

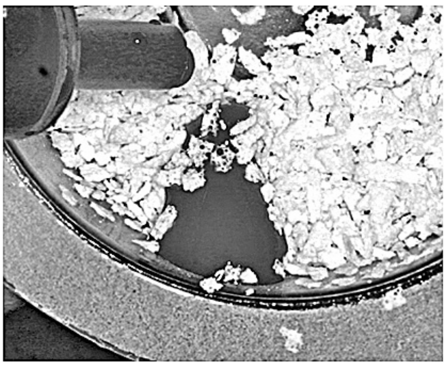

Fig. 2. ChronOS particles with blood just before implantation. Particles are heteromorphic and hydrophobic

Ryc. 2. Cząstki ChronOS z krwią tuż przed zabiegiem. Cząstki są wielokształtne i hydrofobowe

Immediately after the surgery was completed, intra-oral radiological examination was taken. Digora Optime digital radiography device (Soredex, Finland) and X-ray apparatus Focus (Instrumentarium Dental, Finland) were used. Technical parameters of exposure were the same in all included cases: 7 mA, 70 mV and 0.06 s. Radiographs were taken in a standardized way [8]. A modified RINN (Dentsply Rinn, USA) system was applied. A bite index was prepared using a silicone material (occlusal bite duplicates the shape of the film plate holder and also occlusal surfaces of the teeth). The X-ray detector was placed in the RINN positioner and the bite index with the connection bar and ring was replaced in the mouth of the patient then fixed to the tube. Follow-up examinations were performed in the same condition 6, 12, 18 and 24 months post-operatively.

Regions of interest (ROI) were selected in radiographs. The ROI outlining limit was the line running on the external border of the bone substitute materials image. Another region of normal bone with the least diverse gray level were also selected in the radiographs as a reference.

Total registered number of gray levels was decreased to 128, to reduce random noise in the analyzed data. Then each ROI optical density was normalized according to mean (mean ± 3 standard deviation of optical density). Co-occurance matrix was analysed in MaZda ver. 4.5. The second-order histogram was defined as the co-occurrence matrix $h_{d\theta}(i,j)$ [9]. When divided by the total number of neighboring pixels $R(d,\theta)$ in ROI, this matrix becomes the estimate of the joint probability, $p_{d\theta}(i,j)$, of two pixels, a distance of 5 pixels apart along a given direction θ having particular (co-occurring) values i and j. Formally, given the image $f(x,y)$ with a set of 128 discrete levels of optical density, the matrix $h_{d\theta}(i,j)$ is defined such that its (i,j)th entry is equal to the number of times that

$$f(x_1 y_1) = i \text{ and } f(x_2 y_2) = j, \text{ where} \qquad (1)$$

$$f(x_2 y_2) = f(x_1 y_1) + (d \cos \beta, d \sin \beta). \qquad (2)$$

This yields a square matrix of dimension equal to the number of intensity levels in the image, for selected distance of 5 pixels and orientation θ. Angles $\theta = 0°, 45°, 90°$ and $135°$ were investigated. Aritmethical mean of these four directions was calculated due to eliminate directional dependence.

Sum of average of co-occurance matrix was extracted to describe bone structure variability [10, 11]. It is defined by the equation that follow (3), where μ_x denotes the mean of the row sums of the co-occurrence matrix (related to the marginal distributions $p_x(i)$ and $p_x(j)$).

$$SumAverg = \sum_{i=1}^{128} i p_{x+y}(i), \text{ where} \qquad (3)$$

$$p_{x+y}(k) = \sum_{\substack{i=1 \\ i+j=k}}^{128} \sum_{i=1}^{128} p(i, j) \qquad k = 2, 3..., 128. \qquad (4)$$

The geometric adjustment was performed with the use of ToothVis program on the radiographs of each patient, about 4–5 reference points were selected. On the basis of these points, the program matched the radiographs with each other. Then, using MaZda ver. 4.5 program, the reports regarding parameter sum of average co-occurrence matrix for each patient's radiographs were calculated.

Statistical analysis was performed in Statgraphics Plus for Windows ver. 5.1. T-test was used to compare the means of the two samples. It determines the statistically significant differences between the two samples as $p < 0.05$. Next, ANOVA was applied to reveal the factor which influenced the variability of texture. Gender, surgical procedure (tooth removal, apicoectomy, cyst enucleation) and localization of the bone defect were established as factors.

Results

There are no statistically significant differences within Cerasorb group during 24-month observations. Radiological texture was different from reference bone from the day of Cerasorb implantation up to 12 months post-operatively. During second year after surgery, implantation site had the same structure as intact bone (Figs. 3 and 4).

Within-group variability in ChronOS cases was not revealed. There is no difference between ChronOS and reference bone too. During all period of experiment, the radiotexture of this biomaterial inserted into the bone defect was similar to intact bone. Results are presented in Table 1.

None of the factors (gender, surgical procedure, bone defect localization) have a statistically significant effect on texture in site of implantation ROI despite of gender in Cerasorb group at 9 months after surgery (for female: 64.61, for male: 65.59; $F = 9.92$; $p = 0.005$), and localization after 24 months post-operatively (for maxilla: 64.88; for mandible: 65.67; $F = 4.98$; $p = 0.044$). In ChronOS group, gender interfere the effect of treatment at 3 months after surgery (for female: 65.46; for male: 64.20; $F = 7.02$; $p = 0.027$).

Moreover, there is a statistically significant relationship between bone radiostructure 24 months post-op and age of the patient in ChronOS

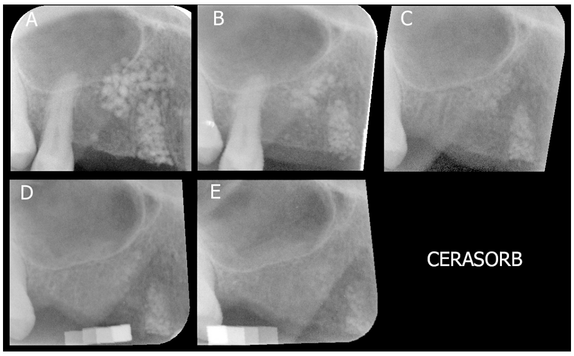

Fig. 3. A) Cerasorb implantation site in female patient after tooth 12 and radicular cyst removal, the radiological texture is different from reference bone till the X-ray F); B) 6 months after the implantation; C) 12 months after the implantation; D) 18 months after the surgery, then the implantation site has the same structure as intact bone; E) 24 months after the implantation

Ryc. 3. A) Implantacja materiału Cerasorb u pacjentki po ekstrakcji zęba 12 i usunięciu torbieli korzeniowej, struktura radiologiczna jest odmienna od referencyjnej kości do ostatniego badania (F); B) 6 miesięcy po implantacji materiału; C) 12 miesięcy po implantacji materiału; D) 18 miesięcy po implantacji, miejsce zabiegu zaczyna mieć strukturę podobną do nienaruszonej kości; E) 24 miesiące po implantacji

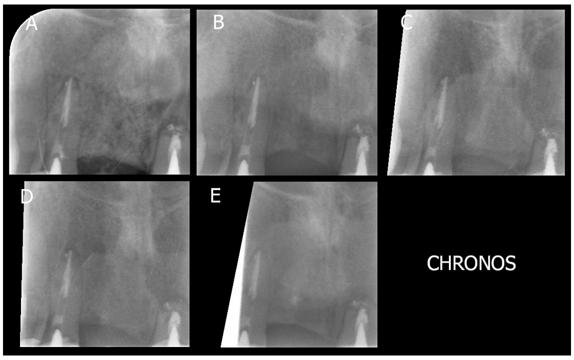

Fig. 4. A) ChronOS implantation site in male patient after tooth 11 and radicular cyst removal. The implantation site has the same structure as the reference bone during 24-months observations; B) 6 months after the implantation; C) 12 months after the implantation; D) 18 months after implantation; E) 24 months after the implantation

Ryc. 4. A) Implantacja materiału ChronOS u pacjenta po ekstrakcji zęba 11 i usunięciu torbieli korzeniowej. Miejsce implantacji ma taką samą strukturę, jak referencyjna kość przez 24 miesiące obserwacji; B) 6 miesięcy po implantacji; C) 12 miesięcy po implantacji; D) 18 miesięcy po implantacji; E) 24 miesiące po implantacji

Table 1. Co-occurance matrix data (sum of average) for Cerasorb and ChronOS implantation sites

Tabela 1. Dane z macierzy zdarzeń (suma średnich) dla miejsc implantacji materiału Cerasorb i Chronos

Bone substitute material (Materiał kościozastępczy)	Immediately post-op (Bezpośrednio po zabiegu)	6 months post-op (6 miesięcy po zabiegu)	12 months post-op (12 miesięcy po zabiegu)	18 months post-op (18 miesięcy po zabiegu)	24 months post-op (24 miesiące po zabiegu)	Reference bone (Kość referencyjna)
Cerasorb	65.42 ± 1.06 REF	65.47 ± 1.04 REF	64.96 ± 0.75 REF	64.84 ± 1.00	64.73 ± 0.77	64.24 ± 0.67
ChronOS	64.41 ± 0.77	64.37 ± 0.66	64.22 ± 0.91	64.45 ± 1.00	64.55 ± 0.60	64.24 ± 0.67
Between-group difference (Zróżnicowanie międzygrupowe)	*	*	n.s.	n.s.	n.s.	

* Cerasorb versus ChronOS between-group difference as $p < 0.05$.
REF difference to reference bone as $p < 0.05$.
n.s. not statistical significant.

* znamienna różnica międzygrupowa Cerasorb w stosunku do ChronOS dla $p < 0,05$.
REF różnica znamienna w stosunku do kości referencyjnej dla $p < 0,05$.
n.s nieznamienne statystycznie.

group (CHR24M). The R^2 statistic indicates that the model as fitted explains 67.67% of the variability in bone texture. The correlation coefficient CC = –0.82 indicates a moderately strong relationship between the variables. The equation of the fitted model is $CHR24M = 1/(0.01576 - 1.84609\times10^{-7}\times\times Age^2)$. The investigated bone texture parameter value increases depending on patient age.

Discussion

The process of new bone creation starts from the blood protein adsorption [12, 13], the rate of which depends on bone substitute material structure [14]. The difference in surface structure may then have profound effect on the protein adhesion and the following process of cellular attachment. ChronOS and Cerasorb are both porous materials with various pore diameter and different micromolecule size, which can be attractive to the proteins and the cells. ChronOS's pore diameter amounts 20–500 µm, and the micromolecule size is 2–5 µm [15]. On the other hand, Cerasorb's pore diameter is 1–8 µm and micromolecule 4–8 µm [16]. Both biomaterials can form scaffold, which provides a good structure for osteoconductivity. The next phase of new bone creation is an attachment phase, in which physical and chemical interactions between cells and material take place [14]. That step is falloved by adhesion phase, when osteoblast adhesion appears [14]. The most important parameters in cell interaction are surface topography – size [17], shape [17, 18], surface texture [19] of the material and the physical and chemical features [15, 16] of surface.

One of the bone substitute material feature is the creation of scaffold (which can be observed radiologically). The products from scaffold disintegration may become then the substrate for new bone deposition. During bone substitute material resorption, the calcium and phosphatic ions are created in that place. These ions have the ability to mineralize the newly created connective tissue from which a new bone is created.

The radiological homogeneity of ChronOS in first months of this investigation developed from the shape of its particles. The particles visible in radiolographs are similar in respect to applied run–length matrix parameter to reference bone. But later, the observed similarity derived from ability to normal bone formation on scaffold of ChronOS particles, contrary to Cerasorb. Granules of Cerasorb first must be significantly resorbed, and next revealed its osteoconductive potential, leading to bone regeneration. Final osteologic effect of both tested materials is the same: *restitution ad integrum*.

Result of treatment is independent on the type of performed surgical dento-alveolar procedure. Further study should be done to evaluate this age interfere, as well gender and localization variability.

Concluding, application of beta-tricalcium phosphate bone substitute materials leads to as proper reconstruction as the reference bone structure is, independently on brand of investigated products. Shape of biomaterial particles influences to its recognition within implantation site during initial six month after implantation.

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